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Vol. 27 : No. 176 MAY, 1960 Price 2/6

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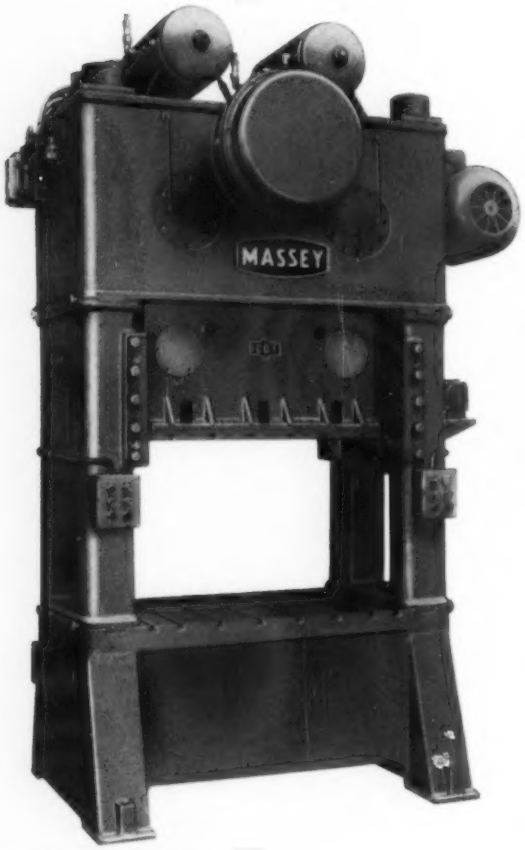
WIDE RAM PRESSES for Trimming, Setting, etc.



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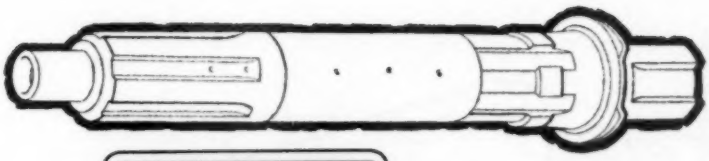

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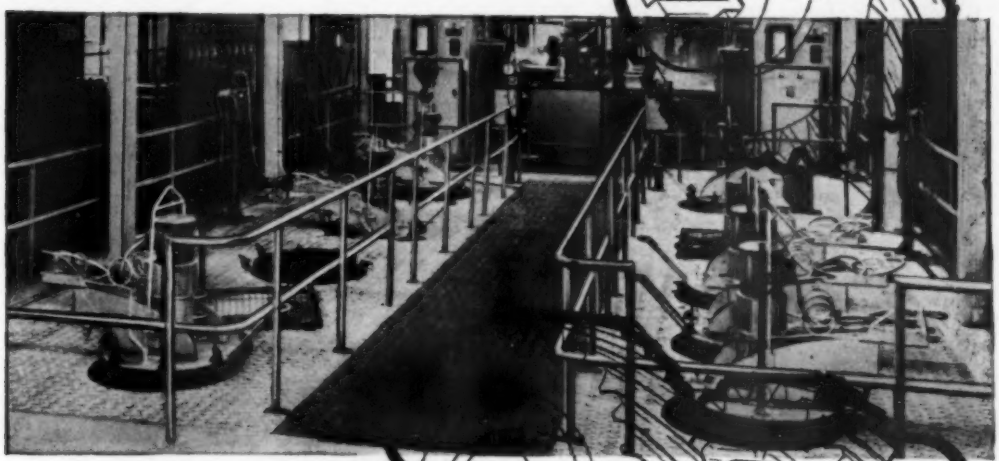

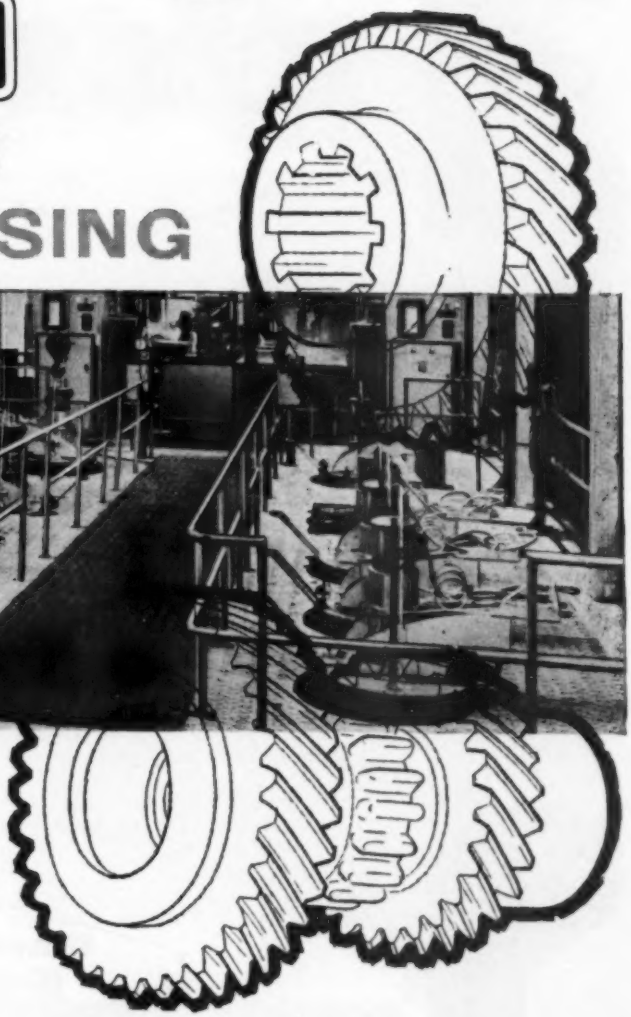

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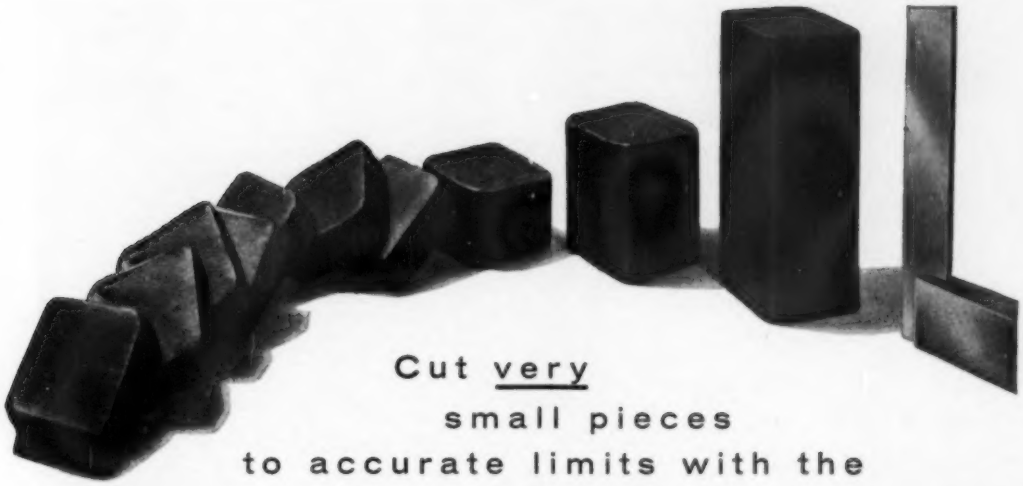

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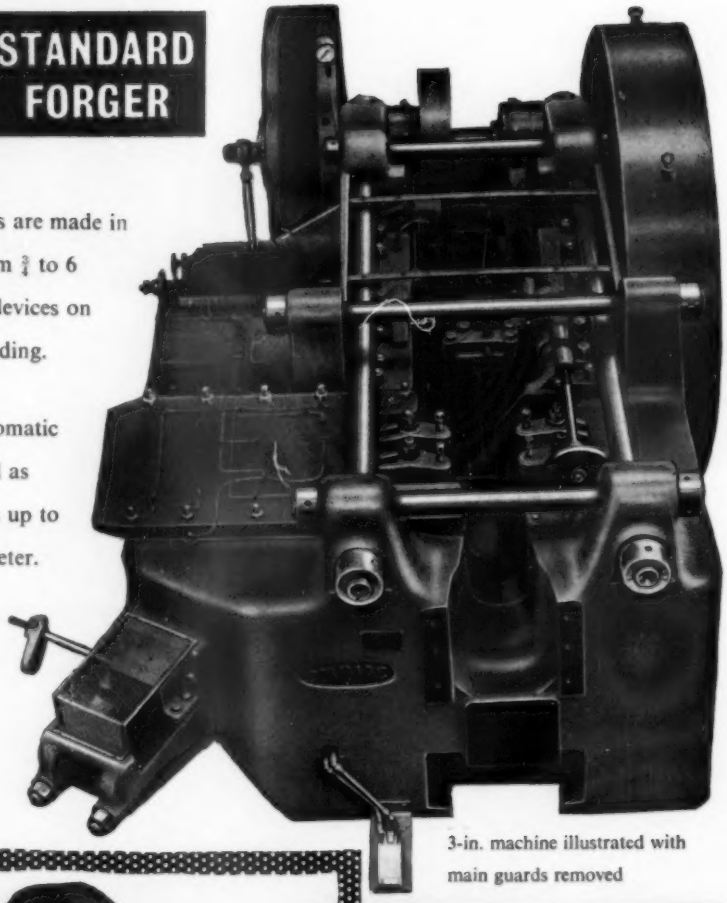
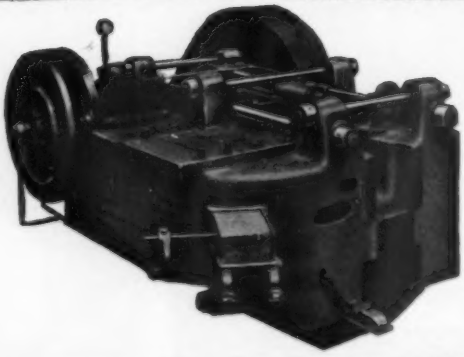


3-in. machine illustrated with main guards removed



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Down the hatch !

And time for a quick sigh of self-satisfaction since this is the last furnace for a complete annealing plant at the new SOMISA steelworks in Argentina. Delivered on time to a very tight schedule, this plant is destined to anneal 300,000 tons of steel a year.

There's not much time to hang about though, for Incandescent is already hard at work on an order comprising all the annealing furnaces for the new Spencer works of Richard Thomas & Baldwins.

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Potentiometer Recording Controllers, SERIES 2000

TYPE 2000 with on/off control
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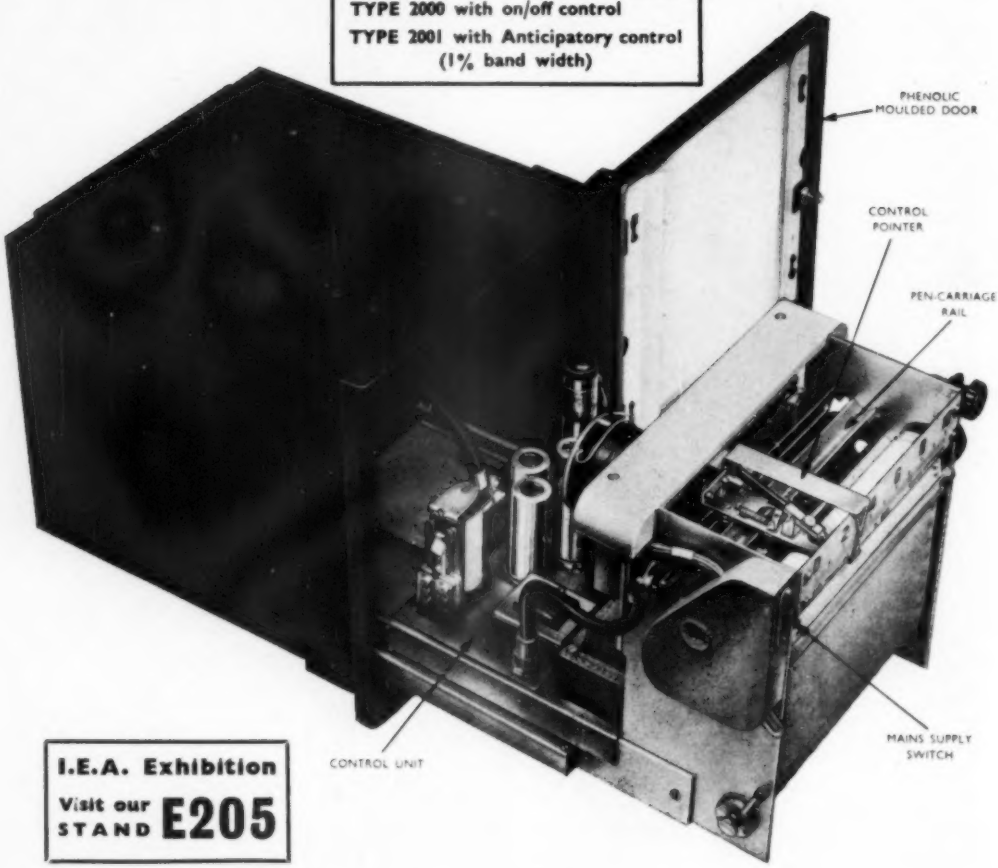

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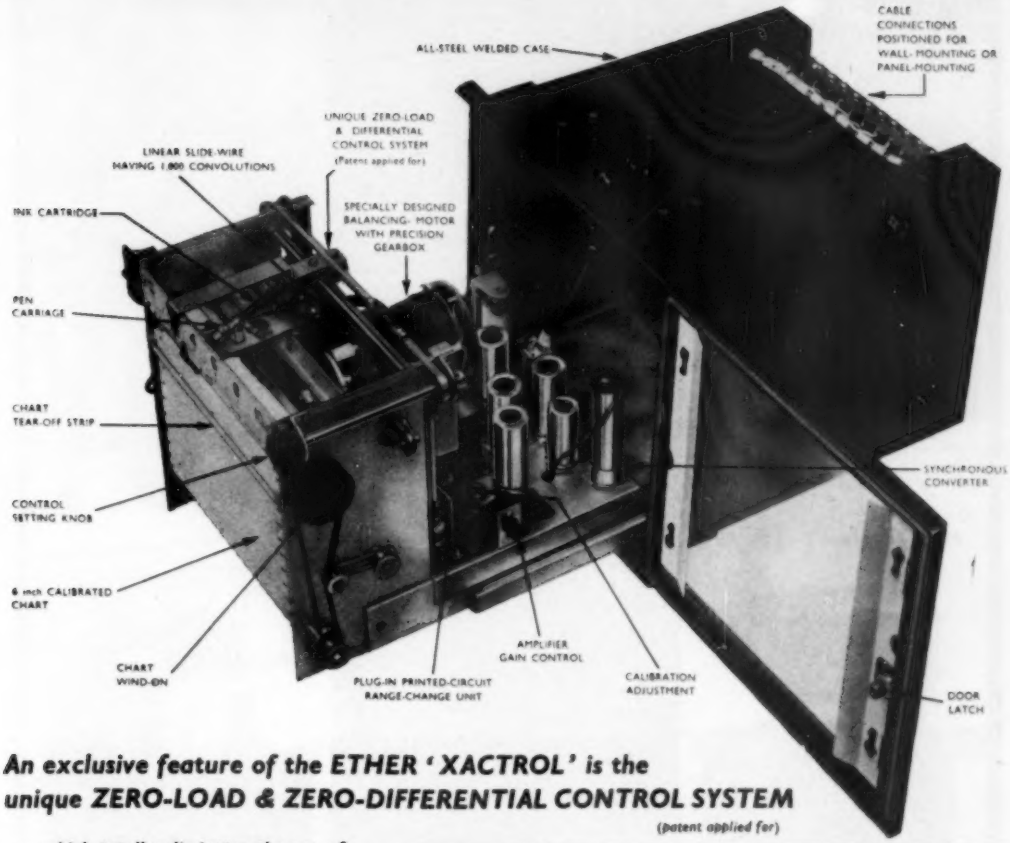

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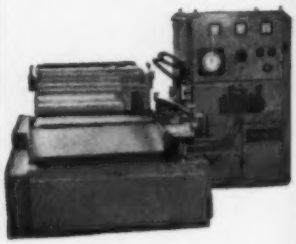
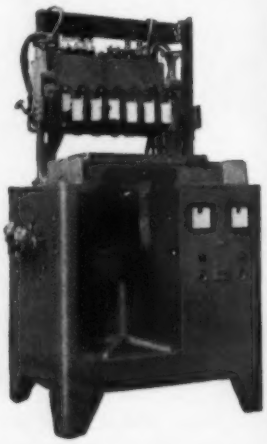
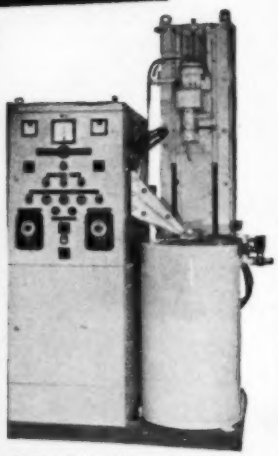
ACEC INDUCTION HEATERS are compact and can be installed exactly where needed. Accurate temperature control puts the final touch to the guarantee of a high quality product.

160 kw 8 k/c "Transaxe" type heater for heating the ends of pins.



160 kw 8 k/c Screw spike heater





Above : Automatic machine for surface hardening of small cylindrical parts

Below : 100 kw 4 k/c heater for tubes

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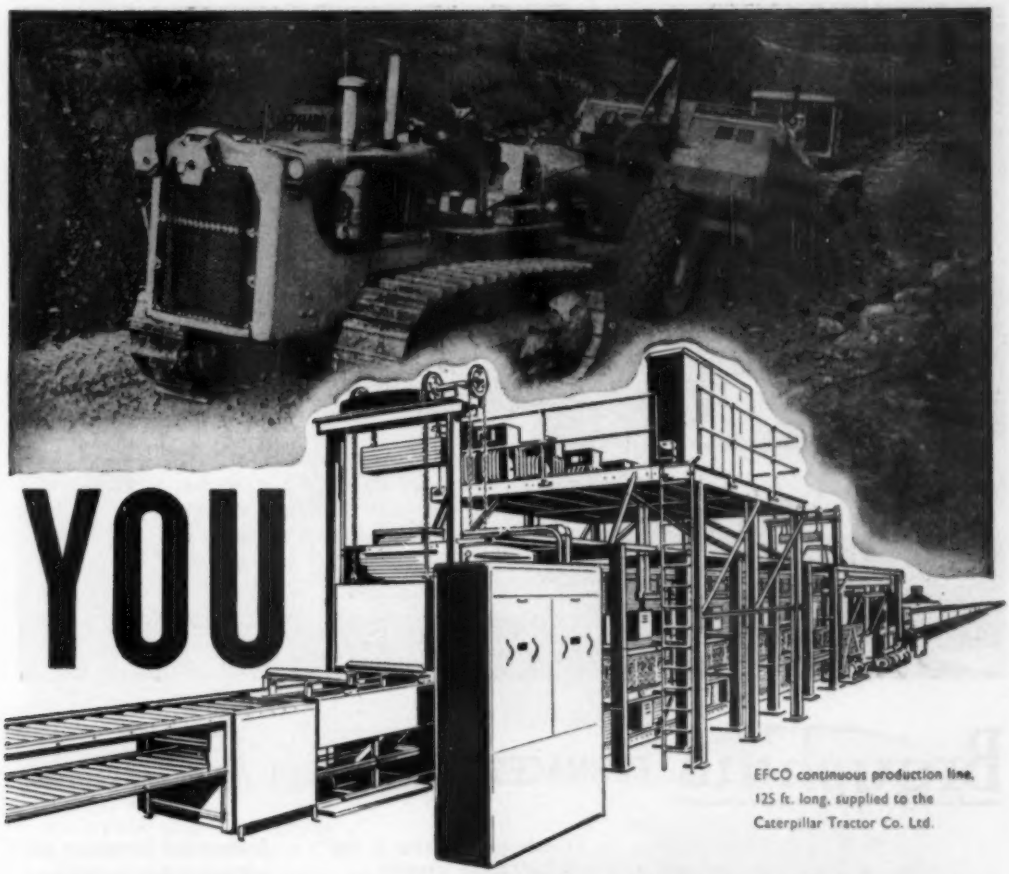

EFCO continuous production line, 125 ft. long, supplied to the Caterpillar Tractor Co. Ltd.

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Models of ruggedness and reliability, Caterpillar tractors need —and get—the finest manufacturing facilities.

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The production line is fully automatic. Here the parts are shepherded along in two lanes to be heated for hardening, are then quenched in water sprays or hurried on by electronic devices to be oil quenched. Further along the line they are cleaned, tempered and cooled. Some 6,000 lb. of tractor components arrive at the discharge end of the line every hour.

The conveyor line, the hardening furnace, quench stations, quenching mechanisms, washing and cooling booths and control gear were all designed and supplied by the Electric Resistance Furnace Co. Ltd.

Now Caterpillar Tractor Co. Ltd. have ordered two more Efco continuous furnaces.

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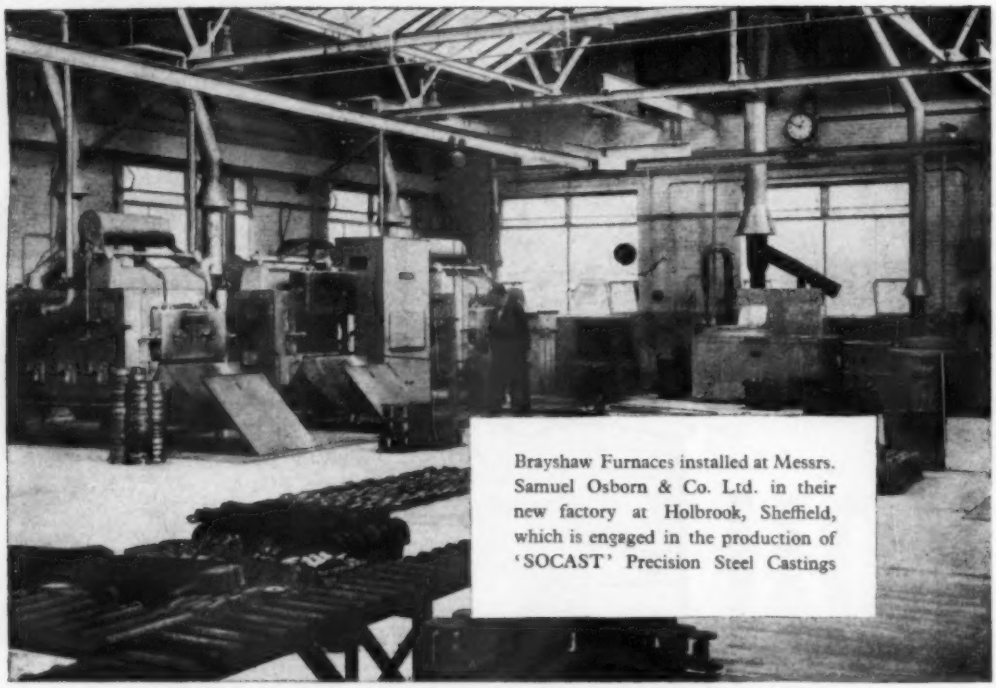

Brayshaw Furnaces installed at Messrs. Samuel Osborn & Co. Ltd. in their new factory at Holbrook, Sheffield, which is engaged in the production of 'SOCAST' Precision Steel Castings

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Once again furnace design by Brayshaw is playing a vital part in a new industrial advance . . . . In the development of their ' SOCAST ' Precision Steel Casting techniques and for the increasing production flow from their new factory Messrs. Samuel Osborn & Co. Ltd. have specified Brayshaw Furnaces. This choice demonstrates a confidence in Brayshaw design and manufacturing ability that is shared in increasing measure by forward-looking concerns the world over.

Brayshaw technical 'know-how,' research, design and production facilities have no equal . . . expert consultation on new projects, re-equipment, conversion, repair and general maintenance of all types of plant is immediately available on request, please do not hesitate to . . . .

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drop forgings for helicopter gears

The main gear wheel and hub assembly of the Bristol Type 192 twin-engined, tandem-rotor helicopter being measured to an accuracy of ·0001. Reproduced by courtesy of Bristol Aircraft Ltd.

A view of the "Wasp" turbine powered helicopter by courtesy of Westland Aircraft Ltd.

Drop forgings for Helicopter Gears and other transmission components must be to A.I.D. Class 1 requirements. Their production can be carried out confidently only by forgemasters whose knowledge and experience are such that they are able to recognise the technical difficulties.

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MR. LOMAN WELCH, first hand melter at the Appleby-Frodingham works of United Steel, Scunthorpe, will go to New York to show how he operates the 'Ajax' furnace. This new oxygen-breathing furnace has a record-breaking output 50% above normal, of finest quality steel.

'AJAX' STEEL FURNACE ▶

U.S. to get an eye-opening look at Britain's modern steel industry

NEW YORK in June. That's when Americans will be rolling up in their thousands at the British Exhibition. And there they'll see an eye-opening display of what Britain's steel industry can do.

Britain led the world in creating plentiful low-cost steel. It was an Englishman, Bessemer, who by inventing his "converter" turned steel from a rarity into an everyday necessity.

Another Englishman, Brearley, discovered stainless steel.

But the accent will be on the modern developments that are putting Britain right in the forefront of steelmaking progress.

One of the highlights of the Exhibition will be 'Ajax', a new type of British steel furnace that is giving record outputs, 50% above normal. 'Ajax' furnaces breathe in oxygen and yield top quality steel in prodigious quantities. Up to 5,000 tons per week and more—from a single furnace!

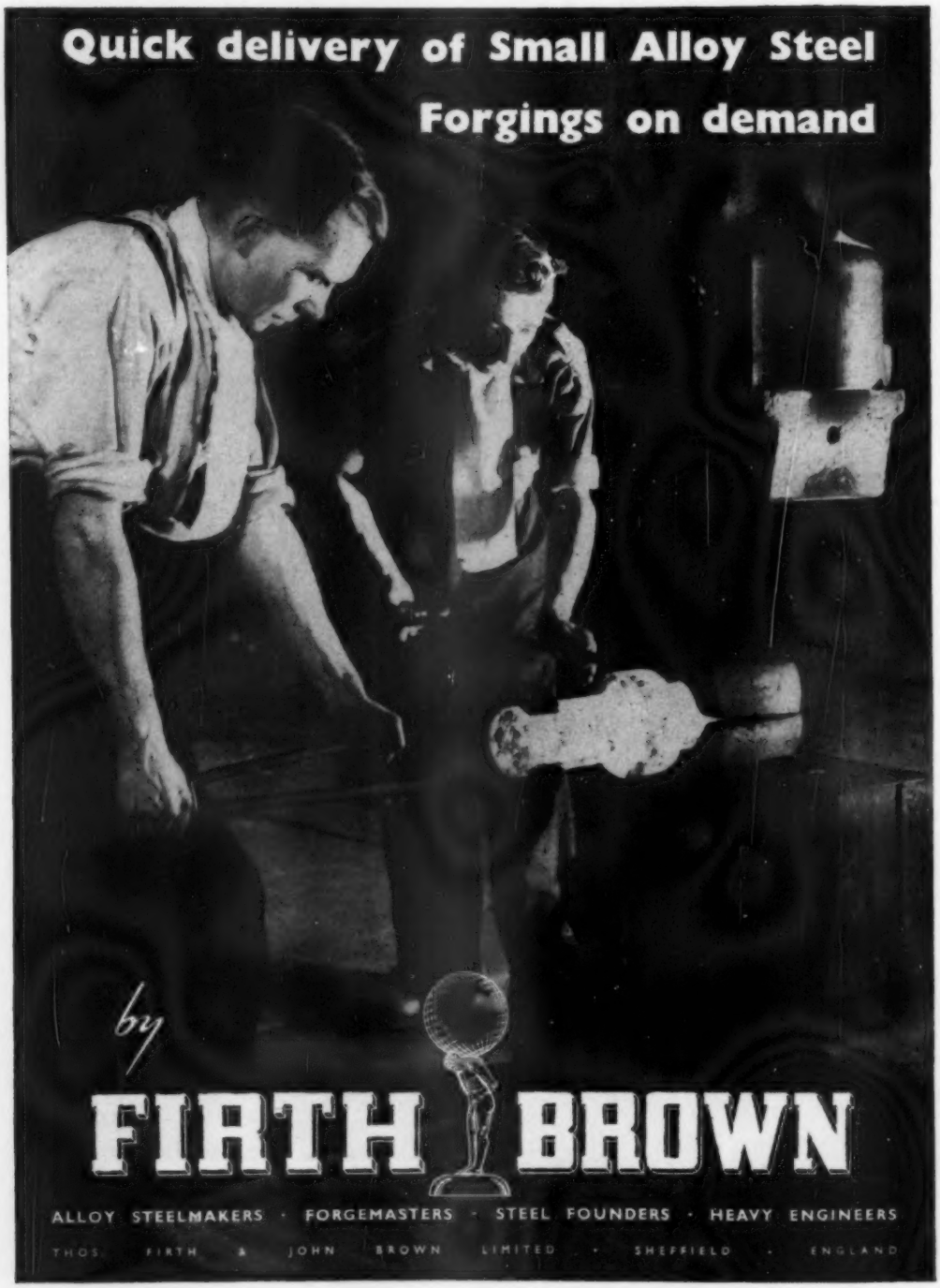
New alloy steels have been developed for use in atomic reactors—including boron steel, which absorbs neutrons. As originally made, boron steel was too brittle to shape: but British steel scientists overcame this difficulty.

Visitors to the Exhibition will learn about some of the superb things made nowadays with British steel, from sports cars to radio telescopes and from precision tools to jet engines. The steel industry will show the vital contribution it is making to Britain's present-day prosperity.

A feature on the steel industry's display in New York forms part of the British Iron and Steel Federation's "Spring Report to the Nation"

The British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1.

ATOMIC REACTOR ASSEMBLY AT DOUNREAY, Scotland, described as "the most complicated stainless steel vessel ever made". This and other British steel triumphs will be featured at the British Exhibition, New York, in June.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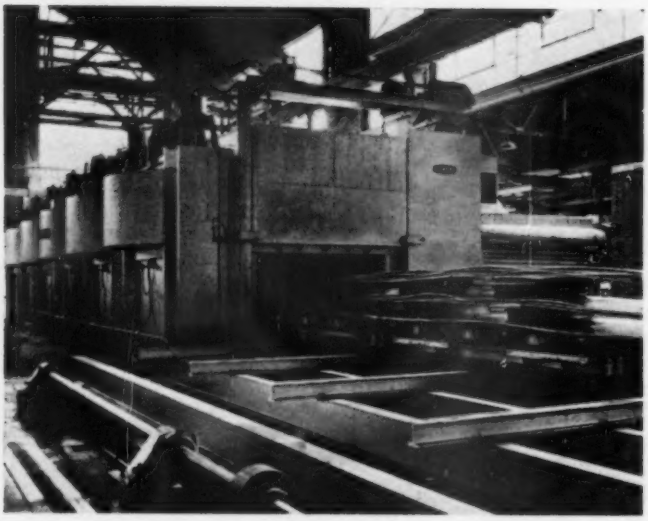

Accommodates slab lengths of 65 ft. x 6 ft. 6 ins.

In the recent large-scale development programme spread over some 30 months, the Northern Aluminium Co. Ltd. has introduced considerable quantities of new plant and handling equipment. A new batch-type furnace, designed and erected by G.W.B. at the Banbury Works of Northern Aluminium, was part of this programme. Production at Banbury, both in aluminium and a variety of aluminium alloys, embraces a wide range of sheets, discs and coils.

Owing to the occurrence of a certain amount of work-hardening (8 in. thick ingots of aluminium are hot rolled to a thickness of approximately 0.3 to 0.5 in.) it is necessary for slabs to be annealed prior to being cold rolled to lighter gauges. The rating of this G.W.B. furnace is 1,000 kW and it comprises six independent and automatically controlled zones of equal length. Rating distribution is as follows: Zone 1 220 kW, Zones 2-5 150 kW each, Zone 6 180 kW. *Owing to the high rating, cycle times as low as 4 hours are regularly obtained.* The maximum temperature of the furnace is 600°C, normal operating temperature being rather lower than this figure.

The heating chamber is lined throughout with heat-resisting alloy, backed by a thick wall of Moler insulating bricks, thus reducing heat losses to a minimum. The furnace casing is constructed from sheet mild steel braced with steel rolled sections and fitted with a mild steel front plate. A cast-framed, refractory faced, fully insulated and counter-balanced door, driven by electric motor, is sealed against the furnace face by pneumatic clamps, thus minimizing heat losses at the furnace entrance. The furnace is supported clear of the ground.

Nickel-chromium strip heating elements, arranged on removable plugs, are situated in the roof chamber, and each zone is fitted with a forced-air circulation system directed cross-flow from the fan, through the heating elements contained in the ducted portion of heating chamber, down into the treatment chamber, and back into the fan for re-circulation. Radiation on to the charge is prevented by a special baffle fitted in the roof chamber to separate the heating elements from the actual working area. Baffles, each independently adjustable and extending the full length of the chamber on each side, direct the air flow to give desired flow characteristics and equalise the temperature throughout the working chamber.

Six air circulating fans are fitted, one per zone. A cooling chamber, similar in size to the heating chamber is incorporated in the unit. A G.W.B. single track charging machine serves both the furnace and the cooling chamber.

As a result of the modernisation, the new rolling mills can roll aluminium sheet to a maximum width of 6 ft. 6 in.; the previous maximum had been 5 ft. The G.W.B. furnace naturally was designed to handle this increased width. It can accommodate loads up to 16 tons for slab lengths of 65 ft. The furnace is normally used to treat slabs of heavy-duty materials for varied employment: Aircraft, coachwork, decorative finishes, car trimming and a host of other uses.

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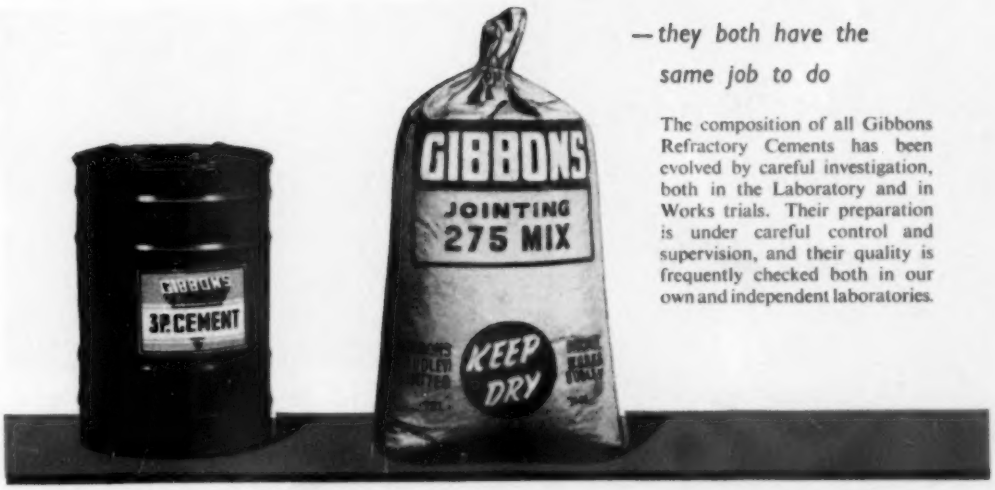

—they both have the same job to do

The composition of all Gibbons Refractory Cements has been evolved by careful investigation, both in the Laboratory and in Works trials. Their preparation is under careful control and supervision, and their quality is frequently checked both in our own and independent laboratories.

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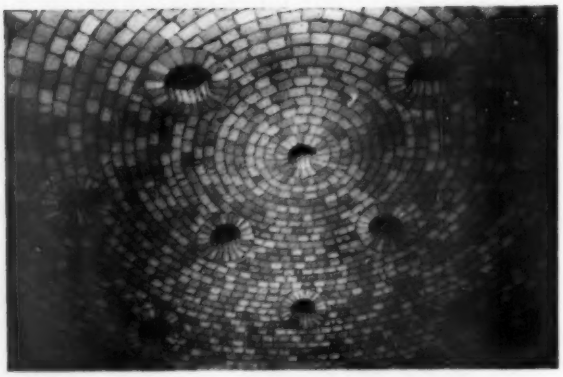
We take our own medicine



Five years ago we began rebuilding the round down-draught kilns of The Morgan Crucible Co. Ltd. at Battersea in MI. 28—a hot-face insulating brick of low thermal capacity that was then comparatively new. The roof of one of these furnaces immediately after installation is shown in the first picture.

. . . (MI. 28 bricks) . . . and like it

The output of these kilns, lined with MI. 28, was considerably greater than their firebrick counterparts, because the low heat-storage of the lining shortened both heating and cooling periods. This, in fact, was the principal reason for the change-over. What we were not so sure of at that time was the life of these linings. We would hardly have dared to expect anything as good as we got. The second picture shows the same roof after *five years* service. So far as we can see it is good for at least another five years and probably longer.

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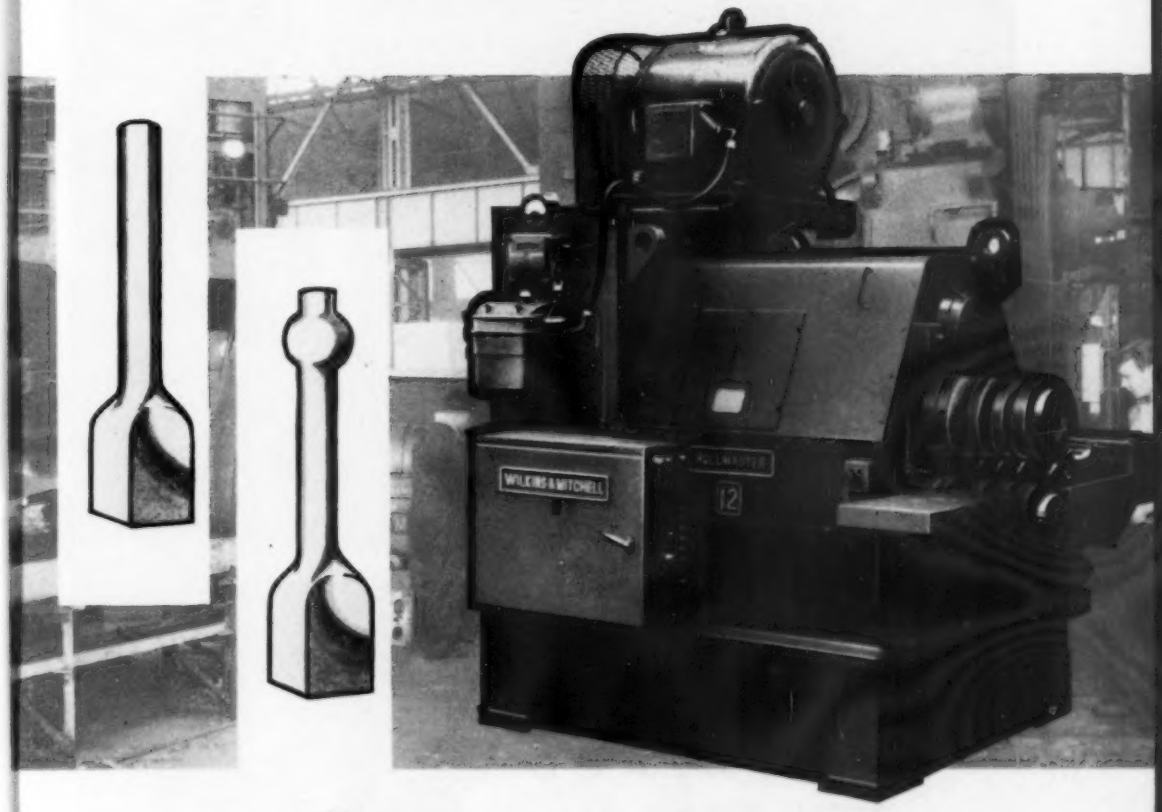

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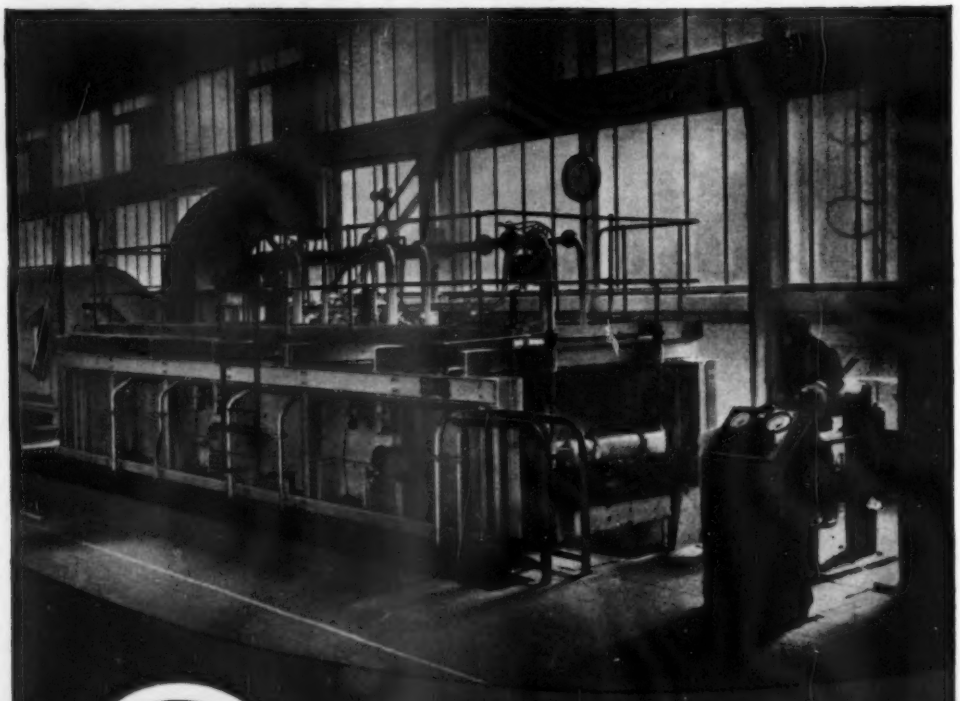

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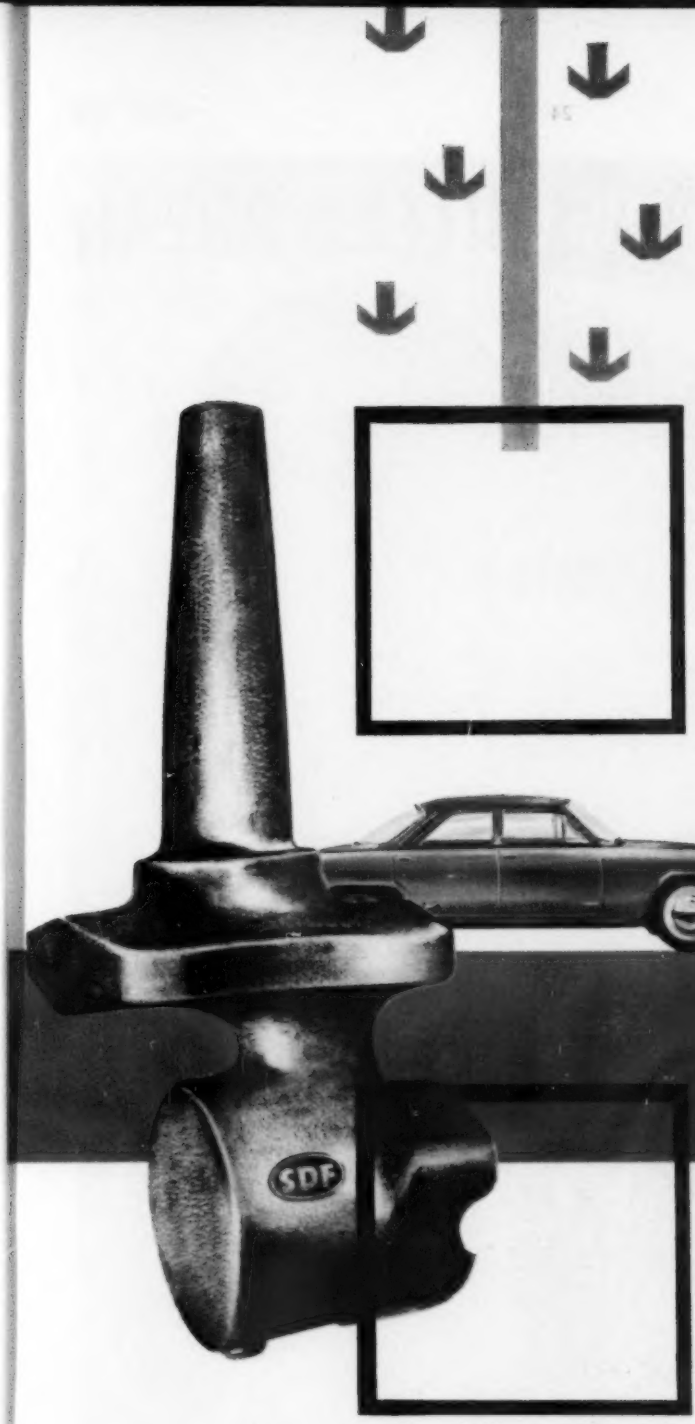

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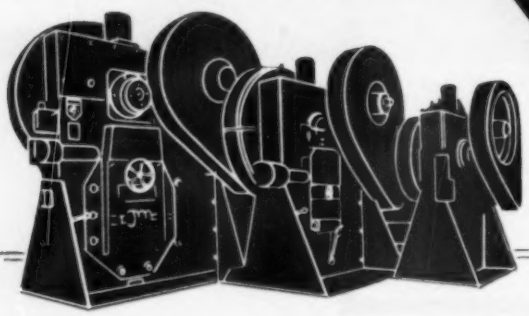

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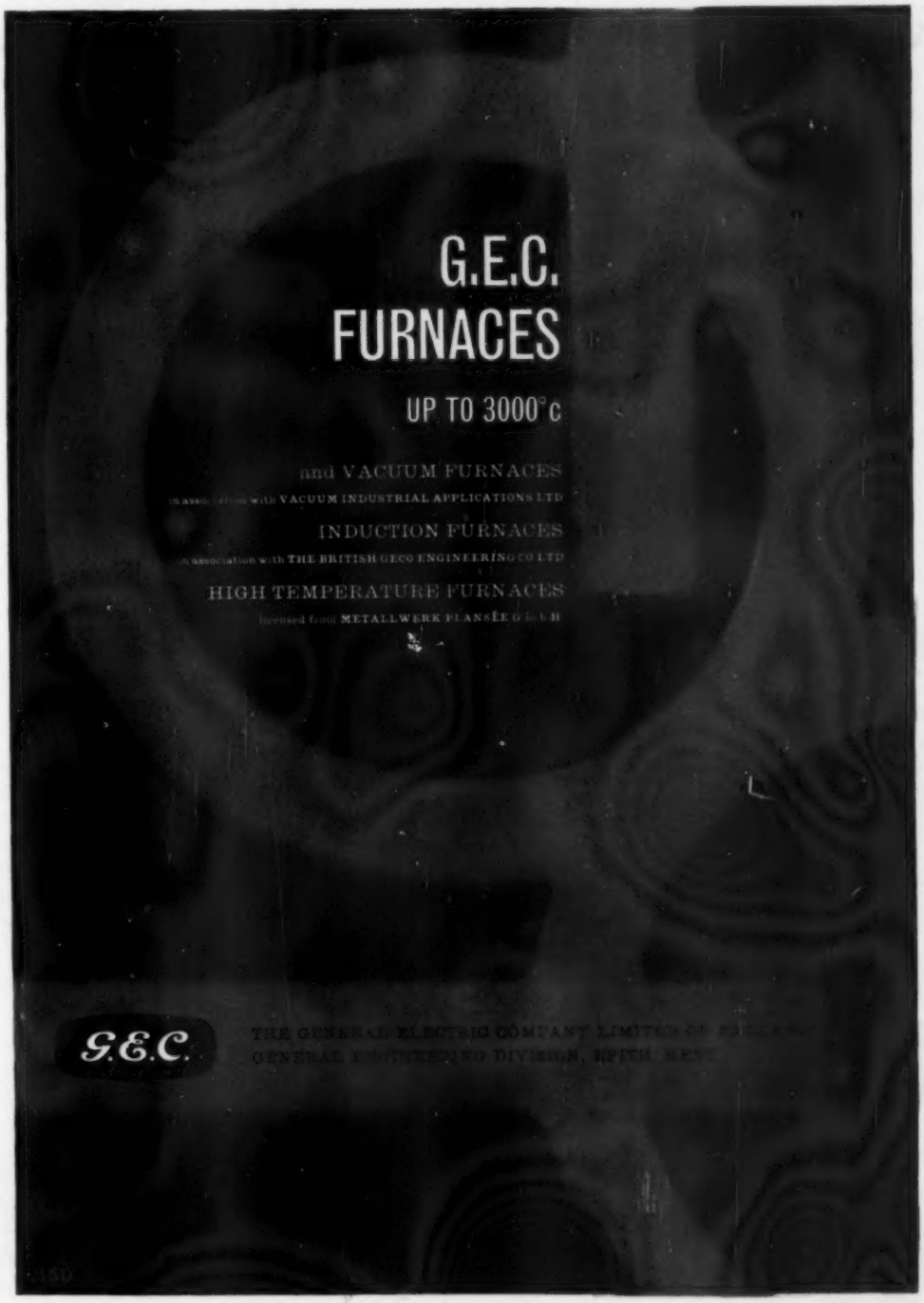
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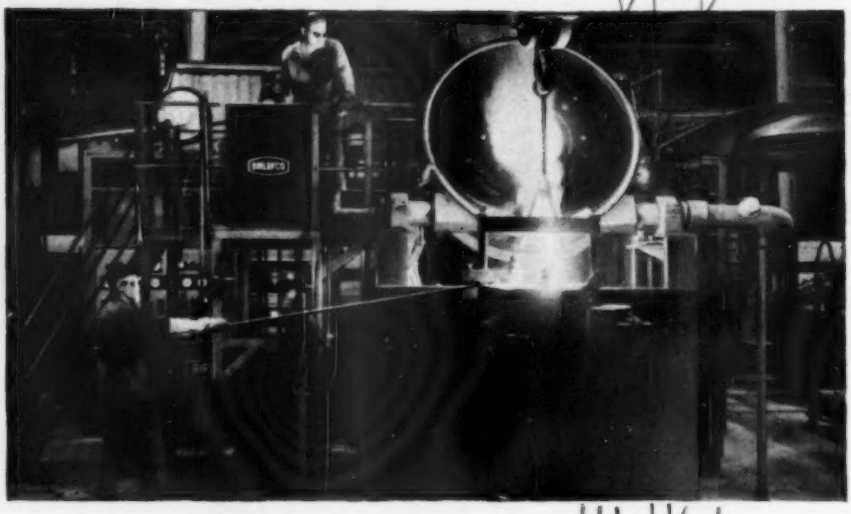
VACUUM REFINING of MOLTEN METAL



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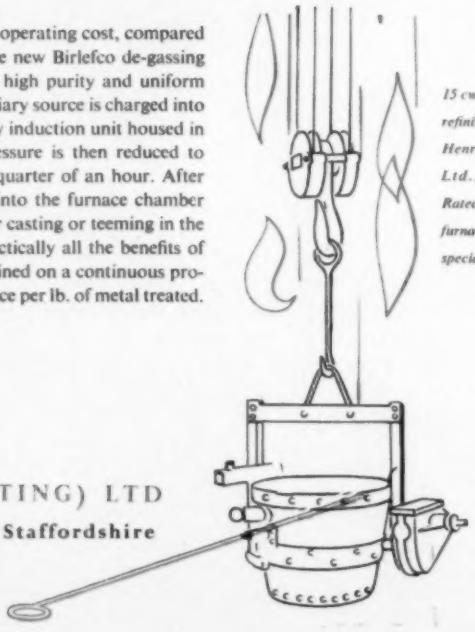

15 cwt. Birlefco vacuum refining unit installed at Henry Wiggin & Co. Ltd., Birmingham. Rated at 300 kW., the furnace is engaged on special alloy production.

BIRLEFCO

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May 1960

Vol 27, No 176

Metal treatment

and Drop Forging

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W.B. 101

Automation, 1960

ALTHOUGH the controversy raging a few years ago as to what was or was not automation has now mercifully lost its sensational appeal, it by no means follows that the questions involved have themselves become unimportant. Indeed, so much has been achieved in instrumentation control in the last few years, the results of which are beginning to be felt even in the most 'traditionalist' industries, that there is now some danger of accepting the advances complacently and forgetting the goals set by a programme of full automation.

At first sight, a conference on control processes in living organisms may seem to have little connections with such work-a-day problems as, say, controlling the temperature of a furnace. Nevertheless, a conference on this subject held two years ago in Essen brought together engineers and biologists and enabled them to benefit mutually by the analogies demonstrated between control loops in the human body and feed-back mechanisms in technology.

There are many bodily processes which, by analogy, can help towards an understanding of the characteristics of true automation as opposed to extended mechanization. One such system is that concerned with ensuring a constant blood temperature essential for the correct functioning of the organism. This is no simple control problem, the 'normal set temperature' may need to change its level as for example when a threatened infection calls for a higher blood temperature as a countermeasure. Safety arrangements with accurately adjusted metering processes are employed to maintain the temperature of the blood. For example, when a physical movement suddenly becomes necessary or certain emotional processes cause an abrupt rise of the 'actual value' of the blood temperature owing to higher combustion in the cells of the body, numerous perspiratory glands all over the body are stimulated to secretion. The rapidly evaporating liquid draws the excess heat from the body so that the 'actual temperature value' is returned to the 'desired value.' These safety arrangements are also actuated if, in the case of great heat or tropical humidity, the normal radiation of the surface of the body is insufficient to dissipate continuously generated heat into the ambient air. Troubles in the control mechanism, exceeding of the positioning range and infinite rise of the actual value, may even be lethal causing what is known as a heat stroke.

This analogy illustrates clearly the essential feature of a truly automated process—adaptability. It shows that what is usually met with even in our most up-to-date plant at present is not yet automation in this sense but a more or less advanced level of mechanization. That this is not just a difference of degree is realized when it is remembered that the self-regulating automated process requires the use of a computer system capable not only of carrying out its preset programme automatically but also of adapting the instructions to accord with changes in conditions during operation.

One important reason why we must keep alive to possibilities of automation lies in our export trade. Last year, Britain exported considerably more electronic control equipment than any other country with the exception of the U.S.A. The Instruments Electronics and Automation Exhibition is just opening again in London and next month the Scientific Instrument Manufacturers' Association are exhibiting British equipment in Moscow. Potential competition is strong, however—Germany is holding an International Congress and Exhibition for Instrumentation and Automation in Dusseldorf this October, and Russia may already be leading in the field of true automation. In any case, automation must play an increasing part in the industrial scene of the future and will both create big problems in the labour and social spheres and at the same time offer big prizes to the countries developing it successfully.

Coin manufacture

THE Royal Mint is installing a large amount of Sherwen electromagnetic vibrating equipment on some of the machines used in the manufacture of coins for countries in all parts of the world. This equipment, designed and manufactured at the Erith Engineering Works of the General Electric Co. Ltd., reduces the manual labour necessary in some of the operations involved. With the latest order, the total electromagnetic vibrating equipment now on order or supplied comprises 18—9 in. by 14 in. and 14—3½ in. by 17 in. Sherwen feeders, and 14—12 in. dia. Sherwen bowl-type feeders.

The metal is received by the Royal Mint in its virgin state, either in the form of ingots (copper, tin, zinc, manganese and phosphorous copper) or in 5-cwt. drums (nickel shot). If required, silver and gold would be received in ingot form.

After reception it is prepared in charges for the furnaces—in the correct proportions required for the type of money to be minted. There are four oil-fired and five high-frequency furnaces. The maximum temperature attained by the furnaces is 1,380°C., this being necessary for cupro-nickel, the alloy most commonly used for present-day coinage.

The charge, which varies in weight depending on the alloy, is set at between 800 and 850 lb. for cupro-nickel. This, when molten, is poured from the furnaces into moulds to make bars of approximately 26 in. by 4 in. by 1 in. thick. These are then passed through several rolling mills and a final gauging mill which reduces the alloy to its right thickness. Due to the work-hardening effect caused by the rolling operations, annealing of the alloy is introduced at appropriate stages. The strips are next cut to the most economical length relative to the coin to be produced, and passed to the presses where the coin blanks are stamped out. A rough sorting, to eliminate imperfectly formed blanks, is then made on a sieve type of table.

Annealing of the coin blanks is followed by blanching in sulphuric acid followed by a solution of soda bichromate. The acid is removed by water washing, and the blanks passed through rotary air driers. After this operation they are transported to the canneluring room where the edge of each blank is compressed to form a raised rim. From here the blanks are passed to conveyors where visual inspection of both faces is carried out. It is at this point that some of the vibrating equipment supplied by G.E.C. plays an important part. In the past these conveyors have been fed manually, the coin blanks being emptied from bags on to ramps and directed on to the belt by hand. The ramps on all these conveyors have been replaced by hoppers and Sherwen feeders providing an automatic feed.

1 *One of the presses in the Royal Mint fitted with a G.E.C. bowl-type Sherwen feeder.* (*G.E.C. Ltd.*)

If beading of the coins is required it is performed at this juncture, but otherwise the blanks pass to the press room where the imprint on both faces and the milled edge (if required) is completed in one operation. There are 53 presses performing this function and in the past the coins were placed in the feed tube by the operator. A changeover is now in process in which Sherwen bowl-type feeders are being fitted to the machines to enable the operator to give his undivided attention to the striking of the coins. So far ten presses have been converted to automatic coin feed, while another four are in the process of being changed over.

Fig. 1 shows one of the presses, and the coin feed and Sherwen bowl-type feeder are clearly visible. With the G.E.C. feeder shown a bag of blanks can be poured into the bowl, these then being vibrated up the spiral which is fitted on the interior of the casing, and passed down into the coin-feeding cylinder. Each bowl is fitted with an electromagnetic vibrator rated at 0·375 kVA. 230 V., and the motion is transmitted to the bowl through 16 mild steel flat springs.

The final operations in minting consist of weighing, overlooking and telling the finished product. Sherwen vibrating feeders are also fitted to these overlooking tables, while Sherwen vibrators assist in the handling of the coins in the telling room.

Application of electron microscopy

Hardened and tempered mild steel structures

STEN MODIN

Three types of low-carbon steel have been heat treated and the mechanical properties compared with those obtained after normalizing. The structures were examined both in an optical and an electron microscope. This work was first reported in Swedish in 'Jernkontorets Annaler,' 1959, No. 6, and the first part of the present version was given last month and is concluded in this issue. Mr. Sten Modin is with the Swedish Institute for Metal Research, Stockholm

Isolation of carbides from the hardened only, and the hardened and tempered, specimens. Chemical isolation of the carbide particles was only carried out for steel E, both on specimens which had been completely hardened through, and also on specimens which had been both hardened and tempered. The thin discs of steel, 0·8 mm. thick, were heated in an atmosphere of pure nitrogen at 1,000°C. for 10 min., and then quenched in the already mentioned solution of sodium hydroxide. After quenching, the structure consisted only of martensite, to judge from its appearance in the optical microscope. As tempering temperatures, 200, 300 and 400°C. were chosen, and the tempering time was 1 h. After tempering the specimens were quenched. The carbide isolation was carried out in the manner previously described.[9]

Experiments with various etchants

Even at a very early stage of the investigation it was noticed that etching with picric acid solution often gave a completely different etch pattern to that produced with nitric acid. The customary 1% solution of nitric acid in ethyl alcohol etches different grains of a phase at varying rates dependent on the orientation of the grain in relation to the surface of the polished section. This fact can complicate the interpretation of microstructures. The normal 4% solution of picric acid in ethyl alcohol does not, on the other hand, emphasize differences in the orientations to the same extent. With this etchant, therefore, in general the different structures could be more easily identified. Figs. 7 and 8 show the same area from a partly hardened, low-carbon steel, on the one hand after etching with 1% nitric acid, and on the other after etching with 4% picric acid. The two photographs serve to show the difference. Nitric acid in amyl alcohol gives an etch pattern which lies approximately between these two. It is often very suitable for electron microscope investigations.

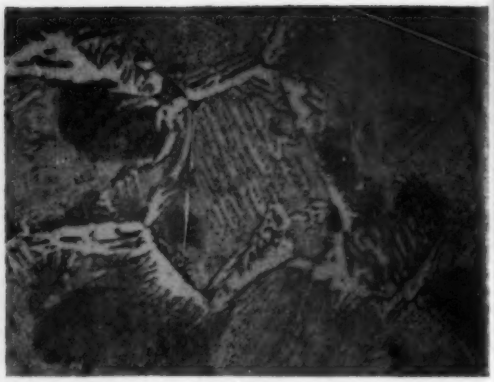
RESULTS OBTAINED

Specimens with completely martensitic structures after hardening

(*a*) *Specimens which were hardened only.* In the specimens which were hardened only, the optical microscope was unable to reveal any precipitation in the martensitic structure (fig. 9). In the electron microscope replicas in exceptional instances an extremely fine structure appeared which could be interpreted as a precipitate (fig. 10). Attempts to obtain an isolate from steel E in the state after hardening only were successful. The quantity of isolate which formed in unit time during the chemical dissolution of the ferrite in the specimen, turned out in this instance to be less than from specimens which were both hardened and tempered. Electron microscope investigation of the isolate showed that for the most part the particles had the form of very thin platelets with a maximum diameter of about 1 micron (fig. 11). At high magnification on their surface there appeared a fine design with a parallel structure, with a distance of about 30–40 Å. between the threads of the pattern (fig. 12). Apart from these platelets, small, irregularly shaped particles were also to be found.

In order to attempt to identify these particles the electron microscope was changed over to diffractography. The diffraction pattern thus came only from those particles which had just been in the field of vision during electron microscope observation.

7 *Etched: 1% HNO_3 in ethyl alcohol. Steel E partially hardened. Optical micrograph* × 750

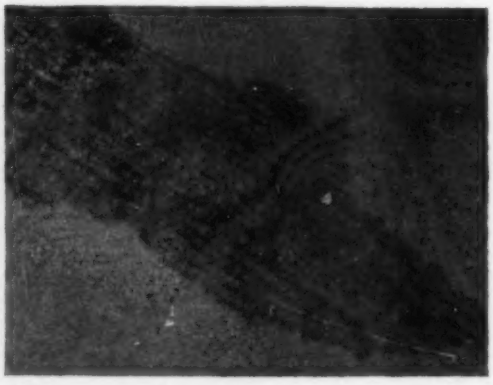


8 *Etched: 4% picric acid in ethyl alcohol. Same area as in* **7.** *Optical micrograph* × 750

9 *Steel E. Martensite. Strong etching in 4% picric acid solution. Optical micrograph* × 2,000

10 *Steel E quenched from 910°C., not tempered. Traces of carbide precipitates. Etched: 2% HNO_3 in amyl alcohol. Electron micrograph* × 5,000

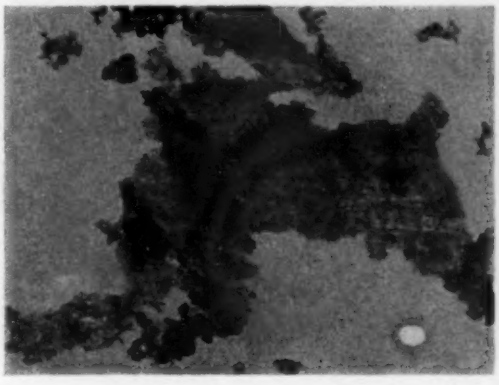
11 *Isolated carbides. Steel E quenched from 1,000°C., not tempered. Electron micrograph* × 38,000



12 *Isolated carbide. Steel E quenched from 1,000°C., not tempered. Electron micrograph* × 150,000

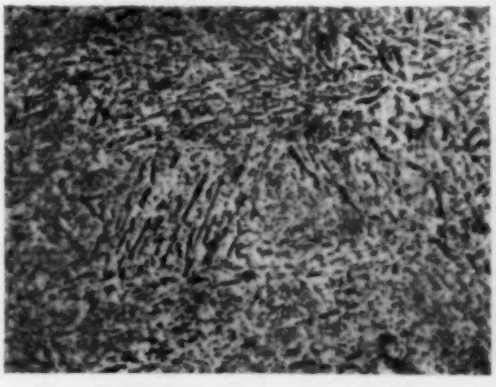
13 *Steel E hardened and tempered at 200°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 1,800

14 *Steel E hardened and tempered at 200°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 7,000

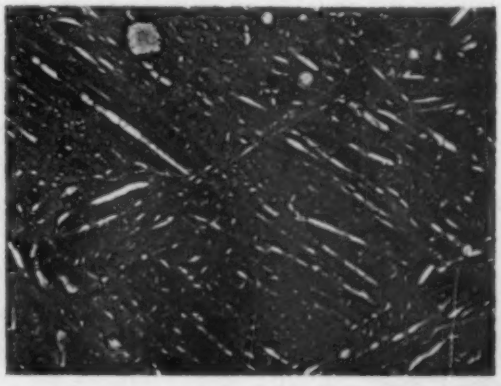


15 *Isolated carbide. Steel E hardened and tempered at 200°C., 1 hour. Electron micrograph* × 38,000

16 *Isolated carbide. Steel E hardened and tempered at 200°C., 1 hour. Electron micrograph* × 38,000

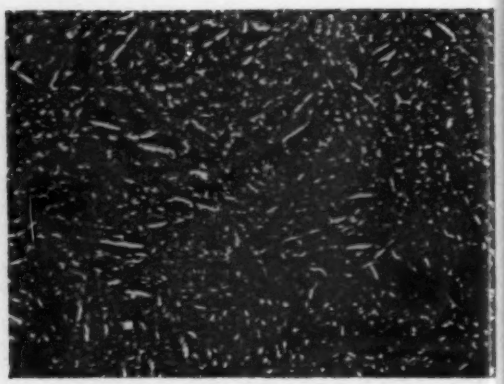


17 *Steel E hardened and tempered at 300°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 1,800

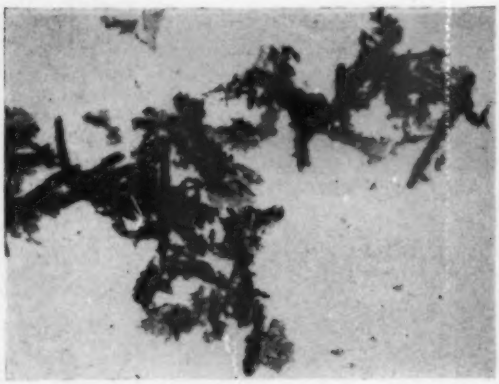


18 *Steel E hardened and tempered at 300°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 4,800

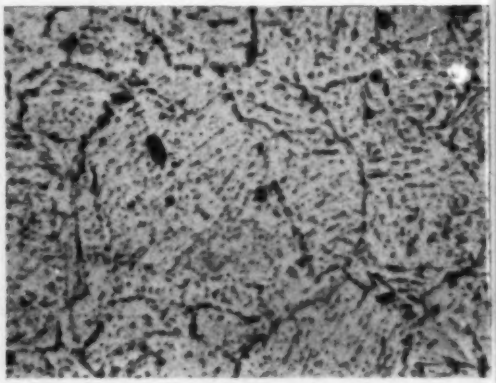
19 *Steel D hardened and tempered at 300°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 5,000



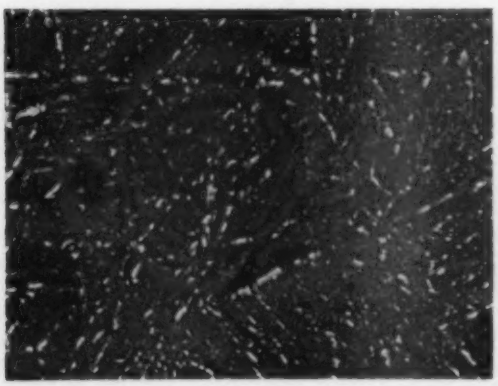
20 *Steel G hardened and tempered at 300°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 5,000



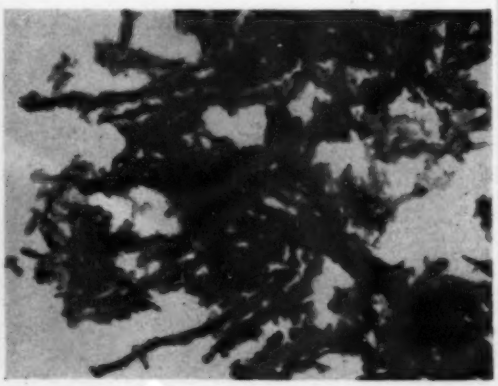
21 *Isolated carbide. Steel E hardened and tempered at 300°C., 1 hour. Electron micrograph* × 16,000



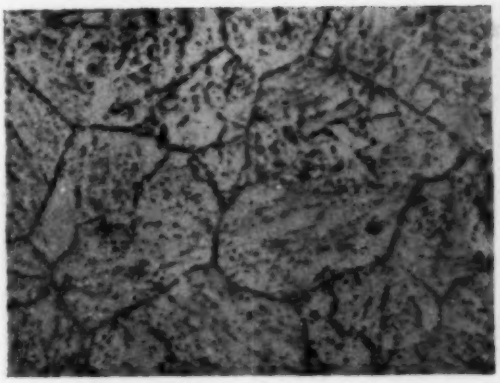
22 *Steel D hardened and tempered at 400°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 1,800



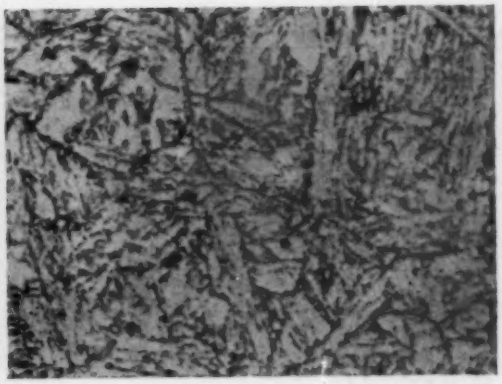
23 *Steel E hardened and tempered at 400°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 7,000



24 *Isolated carbide. Steel E hardened and tempered at 400°C., 1 hour. Electron micrograph* × 34,000

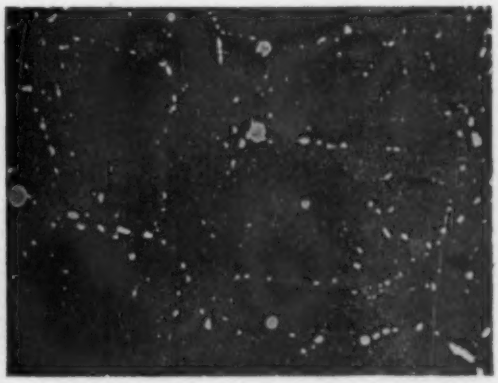


25 *Steel D hardened and tempered at 500°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 800



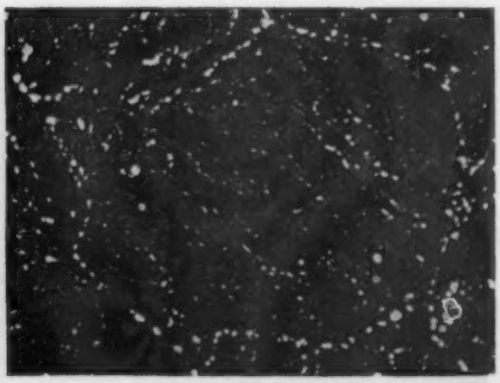
26 *Steel G hardened and tempered at 500°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 1,800

27 *Steel D hardened and tempered at 500°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 3,000

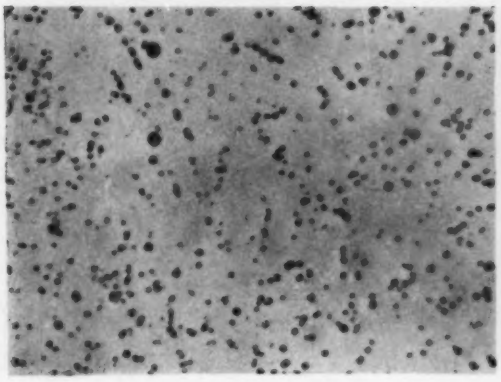


28 *Steel D hardened and tempered at 600°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 3,000

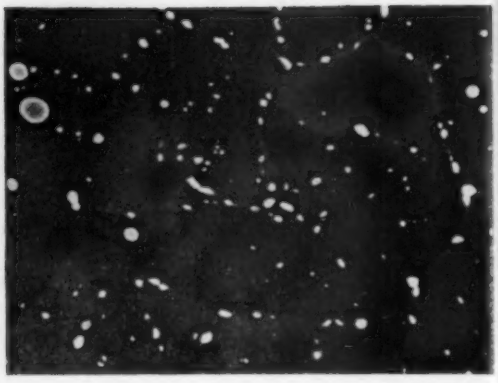
29 *Steel D hardened and not tempered. Etched: 2% HNO_3 in amyl alcohol. Electron micrograph* × 7,000



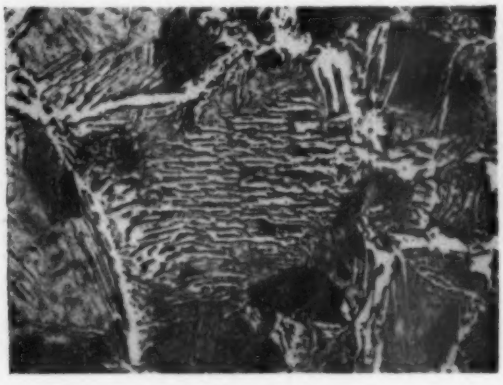
30 *Steel E hardened and tempered at 600°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 3,000



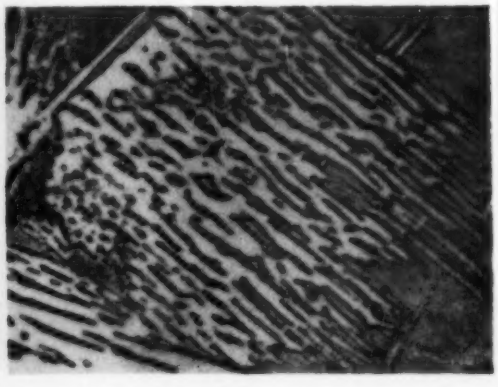
31 *Steel D hardened and tempered at 700°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 1,800



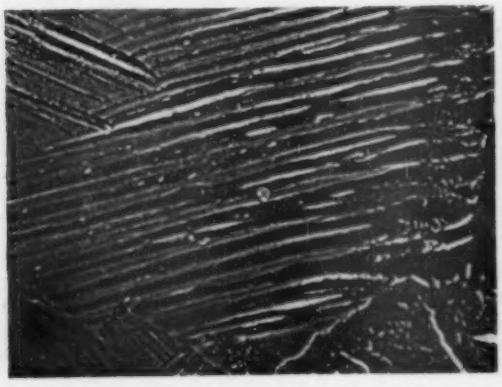
32 *Steel D hardened and tempered at 700°C., 1 hour. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 3,000



33 *Steel E, partly hardenɔd specimɔn, close to the centre. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 750

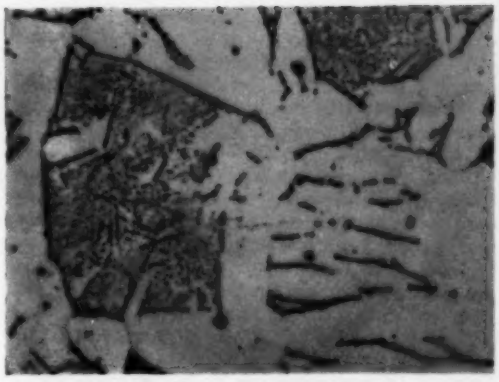


34 *Steel E, partly hardened specimen, close to the centre. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 2,000

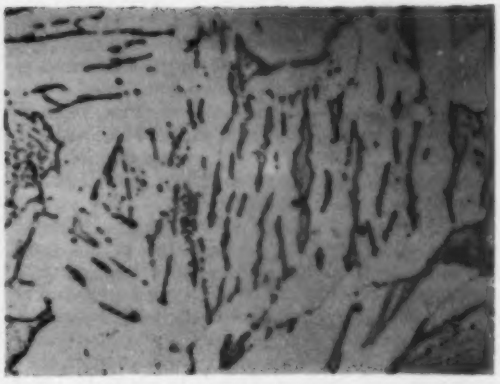


35 *Steel E, partly hardened specimen, close to the centre. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 3,000

36 *Steel E, partly hardened specimen, close to the centre. Etched: 4% picric acid in ethyl alcohol. Electron micrograph* × 7,000



37 *Steel D, partly hardened specimen, close to the centre. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 1,800



38 *Steel D, partly hardened specimen, close to the centre. Etched: 4% picric acid in ethyl alcohol. Optical micrograph* × 1,800

These particles, both those in the form of platelets and the irregular particles, however, gave no diffraction rings. It was, therefore, impossible to determine their lattice structure by this means.

(*b*) *Specimens hardened and tempered at* 200°*C.* In the hardened specimens which were tempered at 200°C., with the optical microscope at the maximum magnification it was possible to see that an extremely fine precipitation had occurred in the martensitic matrix (fig. 13). The electron microscope replicas showed that a precipitation of carbide particles had taken place, partly in the interior of the acicular crystals of martensite, and partly on the grain boundary between two adjacent acicular crystals (fig. 14). Those particles which were on the grain boundary were as a rule larger than those which were within the acicular crystals. But precipitates were not apparent on all the boundaries.

The carbide particles isolated from steel E mostly had the shape of platelets (fig. 15). The size of the platelets was very varied, the greatest having a diameter between 2 and 3 microns, and the thickness was considerably greater than in the untempered specimens. Here, again, at high magnification it was observed that the platelets had a design of parallel lines on the surface, having the same appearance as that of the untempered specimens. As a rule two systems of parallel lines were to be seen, which intersected each other at an angle of about 70° (fig. 16). Apart from these platelets, particles with an irregular shape were also to be found. Electron diffractography produced six moderately diffuse rings. By means of the rings it was possible to identify the particles as being ε-carbide with an edge length of a = 2·73 Å. in the base plane and a cell height, c = 4·33 Å. in the direction of the axis of the hexagon. The rings agree with the six reflection planes, 100, 101, 102, 110, 112 and 004.

(*c*) *Specimens hardened and tempered at* 300°*C.* Both the optical micrographs and also the electron micrographs showed a considerable precipitation of carbides (figs. 17 and 18). The grains of carbide which lay on the grain boundaries of the acicular crystals of martensite often seemed to be noticeably larger than those within the grains. The differences in the appearance of the structures of the three steels were small. But in steel D there seemed to be fewer grains of carbide, which is natural in view of the lower carbon content of this steel (figs. 19 and 20).

The great majority of the carbide particles isolated from steel E had at this tempering temperature a completely different appearance to that of the specimens annealed at lower temperature. They now had a shape of short rods with a length of about 1 micron and a thickness of about 0·1 micron (fig. 21). Apart from this a number of platelets and particles with an irregular external shape were also present. The electron diffraction diagrams produced only weak and diffuse rings, which were unsuitable for a reliable determination of the type of carbide.

(*d*) *Specimens hardened and tempered at* 400°*C.* After tempering at 400°C. it was possible to observe that the distribution of the carbide particles in the ferritic matrix had now started to change. After tempering at the temperatures already mentioned the carbide grains in certain grain boundaries between the acicular crystals of martensite were especially large. At tempering temperatures of 400°C. and above this phenomenon ceased. Instead the outlines of the grain boundaries of the former austenite started to be delineated, either because especially large grains of carbide formed on these

boundaries, or the number of carbide grains in these areas became greater than in the matrix (figs. 22 and 23). This change was most pronounced in steel D, and least so in steel G.

The carbide particles isolated from steel E consisted partly of rod-shaped particles and partly of platelets, which for the most part were elongated (fig. 24). The diffraction diagrams showed only a number of weak cementite rings.

(*e*) *Specimens hardened and tempered at* 500°*C.* The recently mentioned delineation of the grain boundaries of the former austenite by a more profuse cementite precipitation was again most apparent in steel D (fig. 25) and least so in steel G (fig. 26). Likewise another change was seen to have taken place. The previous acicular crystals of martensite occurred much less prominently or not at all. Also this change was most marked in steel D (fig. 27).

To judge from the electron microscope replicas the carbide particles had become shorter and thicker.

(*f*) *Specimens hardened and tempered at* 600°*C.* Only in exceptional instances did the previous acicular crystals of martensite occur in the ferritic matrix. Compare fig. 28 with fig. 29. The ferritic grains had an irregular shape. The grain boundaries of the former austenite continued to be delineated by a more plentiful precipitation of cementite (fig. 30). Apart from this it was also possible to observe that some of the grain boundaries of the ferrite were delineated by a similar precipitation. To judge from the replicas the cementite took the form of nodules. The changes described here were most apparent in steel D, and least so in steel G.

(*g*) *Specimens hardened and tempered at* 700°*C.* The grain boundaries of the former austenite were now no longer prominent (fig. 31). On the contrary sometimes the ferrite grain boundaries were marked by a more profuse precipitation of cementite (fig. 32). By and large, however, the cementite grains were more or less evenly distributed in the ferritic matrix. The number of cementite grains had obviously decreased, while each separate grain had become greater by comparison with the size applicable at the preceding temperatures. They had now acquired an almost circular shape. The grains of ferrite continued to have an irregular external outline and their size seemed to be larger than at the preceding temperatures.

Partially hardened specimens

On hardening the test-pieces from the rods of about 20 mm. diam., the following depths of hardening were obtained: steel D, type 37, 1 mm.; steel E, type 44, 2 mm.; and steel G, type 52, 4 mm. The limit of the depth of hardening was in this instance set as the depth at which 90% of the structure consisted of martensite.

Quenching cracks were not observed. In the martensitic layer after etching the optical microscope revealed light coloured or brown acicular crystals.

During the isothermal transformation of austenite, it is customary to divide the transformation into three temperature ranges according to the nature of the products of the transformation which are formed. Thus we talk of the pearlite, bainite and martensite ranges. Likewise the various transformation products which could occur during the quenching of steel, could be said to be formed within the pearlite, bainite and martensite ranges. Since the transformation takes place during continuous cooling, it is often, however, very difficult to determine in a polished specimen at what temperature a certain transformation product has been formed. If one has access to isothermally transformed specimens of the same steel as that which has been continuously cooled, it is then possible to compare the structures with each other and in this manner obtain a clue as to the temperature range in which the structures formed during continuous cooling have had their origin. Such comparison was possible, since at the Metallographic Institute a steel with almost the same analysis as that of steel E had been investigated after the isothermal transformation of austenite. The result has recently been published.[11]

Within the purely martensitic layer other transformation products start to make their appearance side by side with the martensite. First of all they occur in small quantities, but increase in quantity further in towards the interior of the specimen. On the surface of a cross-section these products thus gradually form a network, which increases in thickness towards the interior of the specimen. This network should delineate the grain boundaries of the austenite. In steel D, however, which has the least depth of hardening, the austenite close to the central axis of the test-piece is transformed entirely within the pearlite or the bainite temperature ranges, so that in this instance it is no longer possible to observe any delineation of the grain boundaries (fig. 37).

These non-martensitic transformation products had a very complicated structure, which was difficult to interpret, despite the fact that comparison could be made with isothermally transformed specimens. Nearest to the purely martensitic layer it was possible to observe ferrite fringes in the earlier austenitic grain boundaries. Somewhat further within the specimen, groups of ferritic lamellae occur, running parallel with each other; they extended from the grain boundaries of the austenite in towards the middle of the grain. At times several such groups intersected each other. Ferrite seemed to nucleate, and to grow along definite crystallographic planes in the austenite,

forming a Widmanstätten structure (figs. 33, 34 and 35).

The areas between these ferritic lamellae also had the form of lamellae, and had a very varied structure. They could be composed either of martensite or of a structure consisting of ferrite and cementite, which at times was reminiscent of pearlite, and at others of bainite.

Side by side with this mixed structure with a Widmanstätten character pure pearlite also occurred. This pearlite seemed to have started from the grain boundaries and to have grown into the austenite with a smooth outline and in a nodular form. In the optical microscope this pearlite had a speckled appearance (fig. 33). Likewise in the electron microscope replicas the pearlite appeared to have an only slightly developed lamellar structure (fig. 36). On the surface of the cross-section small lamellae of cementite were also visible lying in lines interspersed with bridges of ferrite.

The proportion of martensite decreased successively from the surface inwards towards the centre of the specimen. In steel D with the lowest carbon content, as expected, the precipitation of ferrite was the most plentiful (figs. 37 and 38). The areas of pearlite were in this instance often completely surrounded by ferrite. On the boundary between the pearlite and ferrite there was often a fringe of closely packed cementite particles which could touch each other and so in this way form a wall of cementite between the proeutectoid ferrite and the pearlite.

Discussion

By means of this investigation it has been possible to show that low-carbon steels can be given very different mechanical properties by varying the heat treatment, which may consist merely of hardening, or of hardening and subsequent tempering at different temperatures. Carbon steels with contents of 0·09 and 0·18% C, and a steel containing 0·19% C and 1·16% Mn have been investigated. After hardening of tensile test bars of 5 mm. dia., by quenching in a 5% NaOH solution at room temperature as the coolant, tensile strengths of 110, 142 and 155 kg./mm.² were obtained respectively for the three steels, which are about three times higher than the corresponding tensile strengths in the normalized state. Together with these high tensile strengths, values as high as 50 and 10% respectively were obtained for the reduction in area and the elongation. During tempering the tensile strength values then fell continuously with increasing tempering temperatures, while the yield strength first of all rose somewhat at low tempering temperatures, and later fell. Likewise after tempering at the highest temperature of 700°C. the tensile strength and yield strength values continued to remain higher than after normalization. The reduction in area increased successively during tempering, until at the tempering temperature of 700°C. it was higher than after normalization, while the elongation increased to a lesser extent.

During impact testing of specimens which were hardened only without making any notch on them, flexure took place without fracture. Specimens which received the same heat treatment, but which were given a sharp notch, produced impact strength values between 3 and 5 kg. m./cm.² which were largely independent of the test temperature. It is noteworthy that after hardening the lowest impact strength values lay at a higher level than the low values after normalization. At tempering temperatures in excess of 400°C. there was a continuous improvement in the impact strength values, especially within the range of high values of the curves. Tempering within the range of temperatures around 300°C. produced a material with a minimum of impact strength.

The observations which have been made here concerning the mechanical properties of hardened low-carbon steels have likewise been observed by others, *e.g.* Enlund[12] and Aborn.[6]

Interesting results were obtained during the investigation of the structures. By means of chemical isolation of carbides from hardened or hardened and tempered materials, two types of carbides were obtained, differing in appearance. These isolation experiments were carried out only on specimens of material E.

Particles mainly in the form of platelets were obtained from specimens in the hardened but untempered state, and in the state after hardening and tempering at 200°C. By means of electron diffraction, it was possible to identify the particles which were obtained by tempering at 200°C. as being ε-carbide. No diffraction rings were produced by the particles from the specimens which were hardened only. Owing to the similarity in appearance of these particles to those which were formed during tempering at 200°C., it seemed natural to consider that the particles obtained after hardening only were thus also ε-carbide in an early stage of precipitation.

Mainly rod-shaped particles were obtained on tempering the specimens at 300°C. and above. With the increase in the tempering temperature the rods became increasingly shorter and thicker, so that in specimens tempered at 700°C. their shape became approximately spheroidal. The carbide particles from specimens tempered at 400°C. were identified by means of electron diffraction as cementite. The particles isolated from specimens tempered at 300°C. gave too few and weak, electron diffraction rings to make their identification possible

with certainty. On account of their similarity in appearance with the cementite particles which were obtained by tempering at 400°C., it seemed natural to consider them to be cementite.

So far as is known, no one has found ε-carbide after the tempering of martensite with carbon contents of less than about 0·3%. This investigation has shown, however, that also at these lower carbon contents clearly two stages of transformation occur after tempering, at least in unalloyed and low-alloyed steels. In the first stage of tempering ε-carbide is formed. Whether the martensite thereby loses all its carbon, or only a part thereof, proved impossible to establish. It is not entirely excluded that this first stage is identical with the first stage during the tempering of martensite in steels with higher carbon contents, and that in this way martensite of low carbon content is formed together with the ε-carbide. It should be observed that the generally accepted value for this martensite with a low-carbon content, *i.e.* 0·25% C, which is taken to be independent of the carbon content of the steel, has been arrived at on the basis of a determination which is scarcely reliable.[10] The real value could very well be less than 0·18%. It seems obvious that the equilibrium conditions within the martensite-ε-carbide system should be more extensively investigated.

During the tempering of the martensite, in general no even distribution of the carbide particles in the matrix was obtained. At tempering temperatures of 200 and 300°C. the particles precipitated preferentially along the grain boundaries of the acicular crystals of martensite. During the tempering of martensite within the temperature range of 400-600°C., on the other hand, the distribution of the particles became different. In this instance, the particles were precipitated especially along the grain boundaries of the former austenite, which at the lower tempering temperatures were not delineated by the particles. At 700°C. the precipitation of the cementite particles within the matrix became moderately even, although there was some slight piling up of cementite on the grain boundaries of the ferrite and also on the grain boundaries of the former austenite.

Nucleation and growth of the carbide particles took place most easily on the grain boundaries. At low tempering temperatures the boundaries of the martensite provide the most readily available sites. At higher tempering temperatures there was an increase in the mobility of the carbon atoms, and at the same time there was a rise in the solubility of carbon in the matrix. Both these factors contributed to increase the possibility of carbon diffusion. On tempering the martensite at temperatures of 400°C. and above, the cementite was probably precipitated both on the grain boundaries of the acicular crystals of martensite, and also in the interior of the acicular crystals. After the precipitation of carbide the matrix consists of ferrite. After 1 hour's tempering, the ferrite grains no longer had the acicular shape of martensite. This phenomenon has been interpreted as follows. The ferrite recrystallized on account of the residual stresses from the formation of martensite, and very likely also on account of the high grain boundary energy of such a fine-grain structure. Since the grain boundaries of the ferrite were continuously changing their position, they were not delineated by the cementite particles.

The cementite particles, on the other hand, which were precipitated at the points where the grain boundaries of the austenite had previously existed, noticeably grew at the highest rate, so that the boundaries of the former austenite were delineated. This growth of the cementite grains along the relatively disperse grain boundaries of the austenite was made possible by the previously mentioned carbon diffusion. At a tempering temperature of 700°C. the breakdown of the martensite took place very rapidly. The ferrite which had formed then recrystallized quickly, after which there was comparatively little movement of its grain boundaries. The cementite on the grain boundaries then grew more quickly than the other grains of cementite which were in a state of growth. In this way the grain boundaries of the ferrite became delineated at the highest tempering temperatures.

At tempering temperatures around 300°C. the yield strength, as has been mentioned earlier, lay at a higher level than after hardening only, while at the same time the notch impact strength at all the test temperatures showed very low values especially for the steel alloyed with manganese, G. Attempts were made to trace a connection between this mechanical property and the structure. When the steel was hardened but not tempered, the structure consisted to all intents and purposes of one phase only, namely martensite. The small, and presumably few, carbide particles which formed during quenching, and probably likewise during tempering at 200°C., clearly had only a small influence on the mechanical properties. On the other hand there was a complete change in the structure on tempering at 300°C. It is considered that the martensite breaks down completely with the formation of ferrite impoverished in carbon and numerous small cementite particles. It seems probable that the numerous fine cementite particles at this tempering temperature occur in critical dimensions and with a critical distribution, and that thereby the ability of the ferrite to undergo plastic deformation is impaired by the fact that the slip planes are blocked by the cementite particles. These circumstances found their expression in the high yield strength and the increased tendency towards brittle fracture

during the rapid and sudden deformation which takes place during impact testing. This applies to steels E and G.

In specimens which were not fully hardened, very differing types of structures were formed, frequently occurring as mixed structures. At the points where proeutectoid ferrite was formed as a result of the quenching, the austenite adjacent to the ferrite was enriched in carbon, and a carbon gradient was set up in the latter. The transformation products, pearlite, bainite or martensite, which were formed from an austenite of this type, inherited its carbon content which was now often very high.

The pearlite transformation started before the austenite had reached the eutectoid composition. The austenite became saturated in relation to cementite before it approached the carbon content which corresponds to the eutectoid point with reference to the iron-carbon diagram. This circumstance is qualitatively apparent from the diagram, if the A_{cm} line is extended towards lower temperatures. Such a form of pearlite is, so to speak, diluted with ferrite. On the surface of the cross-section it had a more speckled than lamellar appearance. The cementite lamellae in the pearlite will doubtless be extremely patchy and perforated, so that it appearance is almost reminiscent of a grating.

The proeutectoid ferrite precipitated preferentially along the grain boundaries of austenite, and grew from there into the austenite in the form of mutually parallel lamellae, thereby producing a Widmanstätten structure. The areas of austenite enriched in carbon between these ferrite lamellae frequently become martensitic in steels G and E. In steel D these areas were often transformed into ferrite and a coarse form of cementite, and in these instances the ferrite precipitated without grain boundaries on to the already existent ferrite. Where the areas of austenite between the Widmanstätten ferrite were extensive, these areas could also be transformed into speckled pearlite, often with a fringe of cementite towards the proeutectoid ferrite.

The martensite which surrounded the ferrite must have contained a higher concentration of carbon than the average content of the specimen. Martensite of this type with a higher carbon content does not possess the same good toughness as martensite with a low carbon content. In addition, the plastic deformation of such a material is concentrated in the areas of ferrite between the sections of martensite, with attendant concentration of stresses and risk of brittle fracture. These conditions should be strongly contributory reasons why low-carbon steels, which are not completely hardened, possess different mechanical properties to those of steels which have been fully hardened.

Summary

The investigation covered two carbon steels containing respectively 0·09 and 0·18% C, and one steel containing 0·19% C and 1·16% Mn, which were designated respectively D, E and G. Fully hardened specimens were investigated before and after tempering. The selected tempering temperatures included a series of temperatures from 200 to 700°C. at intervals of 100°C. In addition, some incompletely hardened specimens were investigated. The structures produced by the heat treatment were studied in an optical microscope, and after preparation of replicas in an electron microscope. Carbide particles isolated by chemical methods from some of the heat-treated specimens of steel E were investigated in the electron microscope. At the same time electron diffraction diagrams were obtained to determine the types of carbides.

Partially hardened specimens were produced by quenching lengths of 20 mm. round bars. After the end sections were cut off the central section was divided so that the resultant plane was parallel, and close to the central axis, of the bar. The plane surface obtained in the manner described was prepared for microscope observation.

For microscope investigation of fully hardened specimens before and after tempering, 0·8 mm. thick platelets were used, which were prepared after the heat treatments on one of the flat surfaces. The test-pieces for the mechanical property tests were 5 mm. round bars with grips. The test bars for impact testing were similar bars without grips, but provided with a sharp 1 mm. Izod indentation. The check observations of the structure which were undertaken in the optical microscope, after the specimens had been hardened, showed that they were completely martensitic.

After hardening only, both the tensile strength and the yield strength were about three times higher than after normalization for all three steels. During tempering the tensile strength fell almost continuously, while the yield strength rose further to a certain extent during tempering within the range of temperatures of 200-300°C., and only then started to fall. On tempering at over 300°C. the tensile and yield strengths lay close to one another.

After hardening only, the values for the reduction in area for all three steels went up to about 50%. During tempering the reduction in area increased continuously, so that after tempering at 700°C. it was somewhat higher than the value for the normalized specimens. After this treatment tensile strength and yield strength were also higher than in normalized specimens. The elongation values decreased after hardening only to barely 10%, and rose somewhat at tempering temperatures over 400°C.

Impact testing was carried out, as stated, on round 5 mm. bars with a sharp notch. The normalized specimens gave impact strength curves of the usual type. After hardening only, impact strength values of about 3-5 kg. m./cm.^{2} were obtained over the whole range of test temperatures. Only on reaching –80°C. was the fracture completely crystalline. Tempering at 300°C. reduced the impact strength below the above-mentioned value for steel E, and even more so for steel G. At tempering temperatures of 400°C. and above, the impact strength values rose. At the highest tempering temperature of 700°C. the impact strength values for the three steels were in all instances better than after normalization, and it was particularly striking that the transition zones on the impact strength curves from the high to the low values were then markedly displaced towards lower test temperatures by comparison with those of specimens in the normalized state.

From hardened specimens of steel E, tempered at 200°C., by means of chemical isolation small, thin platelets were obtained which it was possible to identify by electron diffraction as ε-carbide. From specimens of the same steel which had been hardened only, an isolate was also obtained. The particles of this isolate had the same appearance as those which were isolated from the specimen tempered at 200°C. They were, therefore, considered likewise to be ε-carbide. On the other hand the carbide particles isolated from specimens tempered at 400°C. had a different appearance, namely rod shapes. Electron diffraction diagrams showed that they consisted of cementite. From specimens tempered at 300°C. for the most part rod-shaped particles were obtained, which produced no clear diffraction rings. On account of the similarity in appearance with the particles tempered at 400°C., these particles were considered to be cementite. At higher tempering temperatures the cementite rods became larger, and their thickness became greater in proportion to their length, to judge from their appearance on the replicas.

The boundaries of the acicular crystals of martensite were delineated by the precipitated carbide particles at low tempering temperatures. At 400°C. and above, on the other hand, the grain boundaries of the former austenite were delineated by a profuse precipitation of cementite particles. At as high a tempering temperature as 700°C. the grain boundaries of the ferrite were also to a certain extent delineated in this way in steel D.

At tempering temperatures of over 400°C. it was observed that the shape of the grains of ferrite was different from that of the former acicular crystals of martensite. It was therefore assumed that the matrix of ferrite recrystallized above this temperature, partly as a result of the residual stresses after the formation of martensite, and partly also probably on account of the high grain boundary energy of such a fine-grain structure; this caused movement of these grain boundaries, and they were therefore not delineated by the cementite precipitation. On the other hand, the cementite which precipitated at the points where the austenite grain boundaries had existed, grew considerably faster than the other grains of cementite, so that the grain boundaries of the former austenite were delineated.

In specimens which were not completely hardened, very different types of structures occurred and often as mixed structures. At the points where proeutectoid ferrite formed as a result of the quenching, the austenite lying adjacent to the ferrite was enriched in carbon, and a carbon gradient was set up in the austenite. The transformation products, pearlite, bainite or martensite, which formed from this form of austenite, inherited its carbon content. Martensite with a markedly higher carbon content than that of the type investigated probably does not possess the same good toughness as a low-carbon martensite. This circumstance should be a strongly contributory reason why low-carbon steels which are not completely hardened possess different mechanical properties to those of steels which have been completely hardened.

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Oslo corrosion exhibition

The correct use of the right material is the slogan of the exhibition Studieselskapet for Norsk Industri (the Norwegian Industries' Development Association) represents in Oslo, May 27 to June 3, 1960. The exhibition is arranged in collaboration with the Norwegian Research Federation.

The exhibition will cover corrosion-resistant materials and coatings, together with methods of surface treatments of iron and metals.

Cold deformation of metals

Part 1—Cold forging

H. Ll. D. PUGH, B.Sc., F.Inst.P., F.I.M.

Studies to increase knowledge of the basic mechanics of deformation of metals have been carried out at the National Engineering Laboratory, East Kilbride, on forging and extrusion as well as on general deformation. A brief account of some of this work was given at the Tenth Technical Convention of the NADFS at Droitwich last November by the author, who is head of the Plasticity Division of the National Physical Laboratory. The article will be concluded next month, together with a summary of the resulting discussion at the convention

THE ABILITY OF A METAL to deform has been exploited in a number of ways to form metals into the required shapes. Some of the formation processes, particularly forging, have their origin in the dim recesses of pre-history. Recently, the greater demand for mass-produced articles before, during and after the Second World War has resulted in marked advances in the practical field.

However, it is in general fair to say that these advances have been due to the skill, intuition and experience of the industry rather than to an understanding of the basic mechanics of deformation of materials in such processes. Considering the importance of formation processes in modern civilization, the amount of effort as recorded in the literature which is devoted to obtaining an understanding of the basic mechanics of deformation of materials in formation processes is very small. This is a state of affairs which cannot be allowed to continue if this country is to maintain, against fierce overseas competition, her place as a leading industrial and manufacturing country. A progressive and healthy industry is markedly dependent on scientific investigations of the basic principles involved in the industry.

In order to increase the knowledge of the basic mechanics of deformation of materials in formation processes, studies were initiated at the National Engineering Laboratory, some years ago, on forging and extrusion, as well as on the general deformation of materials. A brief account of some of this is given in this paper.

Traditional hot working

Forging is a widely-used commercial process, and above all others provides the greatest range of product sizes. At one extreme it is used to shape cast ingots of several hundred tons between parallel platens in large presses into rough forms, and on the other hand it converts short lengths of cropped bar weighing a few ounces into precise forms between closed dies in a hammer. Nevertheless, despite the large range of sizes, the basic mechanics of the process are the same.

Forging, as indeed some other forming processes, had traditionally been regarded as an essentially hot-working process, probably because the limited capacities of the early presses necessitated the heating of the metal to lower its resistance to deformation, thereby permitting the forging of sizeable products. This tradition of hot working has persisted to the present time and metals are still heated prior to forging despite the fact that metals usually have the necessary ductility, even in the cold state, and the required loads are within reasonable press capacity, thus making pre-heating unnecessary.

Quite apart from financial considerations, hot working introduces many complications. The production of scale affects both heat transfer and frictional conditions, with serious consequences, as for example in the closed-die forging of thin sections. Furthermore, in attempting to allow for contraction on cooling, allowances on dimension are made and there is a tendency for the products

to be oversize, necessitating additional machining and material wastage. This, coupled with some 30% loss of metal as flash, results in a low metal utilization factor which may be of considerable economic consequence.

Advantages of cold forging

Cold-forging techniques, however, offer scope for improved metal utilization together with enhanced mechanical properties of the material due to cold working, which are advantageous in many cases. At present the process is particularly suited for axi-symmetric products, but it is not possible to predict whether it will ultimately be applicable to other classes of product now being hot forged.

Over the years, the industry has acquired extensive experience of hot-forging techniques and of optimum working conditions for most materials. One would therefore not expect startling new developments in the basic mechanics of the process or other than marginal improvements. Indeed, in hot forging the most significant improvements are likely to ensue from associated aspects, such as developments in forge mechanization, heating, and material manipulation.

In contrast to hot forging, however, in the case of cold forging there is little background experience. The process requires new techniques of metal preparation; operating stress levels and the limits of reduction to which materials may be subjected are largely unknown, as is the life of press tools. Opinions are divided on the best type of press—mechanical or hydraulic—and detailed information on these and other factors are necessary to assess the full technical and economic potentialities of the process.

Because of these considerations, the initial work at NEL was confined to cold-working processes, because of their considerable potentialities (steel gears, gudgeon pins, cups, etc.), and designed to provide information of immediate and long-term value to industry. The approach was to study the effect on the process of each variable in turn and then attempt to rationalize the behaviour of materials in the process in terms of the different factors, even if only in an empirical manner. This provides a basis for a better understanding of the process and a realistic model for subsequent theoretical studies.

COLD FORGING

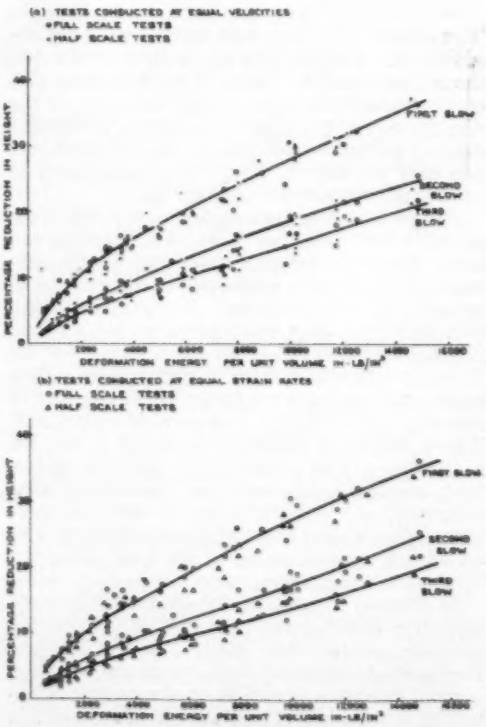
Model tests

Need for model tests. It was clear at the outset that full-scale forging equipment was neither convenient nor desirable for laboratory investigations and that small-scale tests provided a more efficient and flexible control of the essential variables. However, in order to carry out small-scale tests it was first necessary to establish the conditions under which such tests should be carried out in order that the results could be applied to full-scale tests.

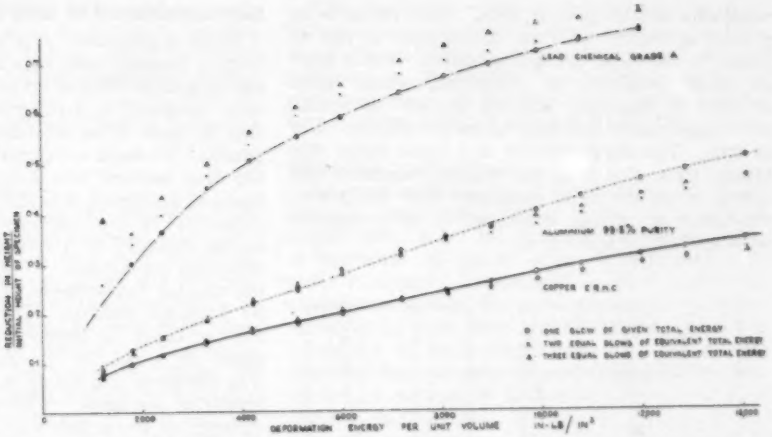
Steady compression tests. The initial investigations were confined to the study of the deformation of metals between overhanging platens. For steady compression, Polakowski[1] had already established the conditions for carrying out valid model tests in a hydraulic press. Our own effort was concentrated on impact compression in a drop hammer.

Dimensional analysis of drop forging. A theoretical dimensional analysis of the process was first carried out and it was shown in agreement with Ilyushin[2] that if the three factors—plastic resistance, inertia and viscous resistance—were all of equal importance, then it was impossible to carry out model tests giving results applicable to the full scale.

Viscous resistance negligible. However, if the viscous resistance were negligible in comparison with the other two, then valid model tests were possible under the conditions already enunciated by Tresca[3] in 1865, *i.e.* that geometrical similarity must obtain, the velocity of the tup in model- and



1 *Model tests on copper ERHC with scale factor of* 2


LEAD CHEMICAL GRADE A
ALUMINIUM 99·5% PURITY
COPPER E.R.H.C
ONE BLOW OF GIVEN TOTAL ENERGY
TWO EQUAL BLOWS OF EQUIVALENT TOTAL ENERGY
THREE EQUAL BLOWS OF EQUIVALENT TOTAL ENERGY
REDUCTION IN HEIGHT / INITIAL HEIGHT OF SPECIMEN
DEFORMATION ENERGY PER UNIT VOLUME

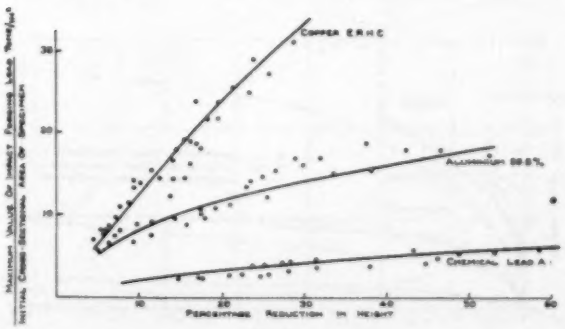
2 *Effect of multiple blows on the reduction in hsight*

full-scale tests should be maintained the same as should also the materials of the tup, anvil and work material.

Tests at equal velocity. Since the average rate of strain during drop-hammer tests can be taken to be proportional to V/h, where V is the impact velocity of the tup and h the initial height of the specimen, then it may be seen that in the tests carried out under the above conditions the rate of strain is higher in the model than in the full-scale tests. Hence it may be seen that if viscous forces were sufficiently large, valid model tests would be impossible. Indeed, this implies that under the conditions given above, the model tests are only valid if the plastic resistance is not significantly affected by rate of strain.

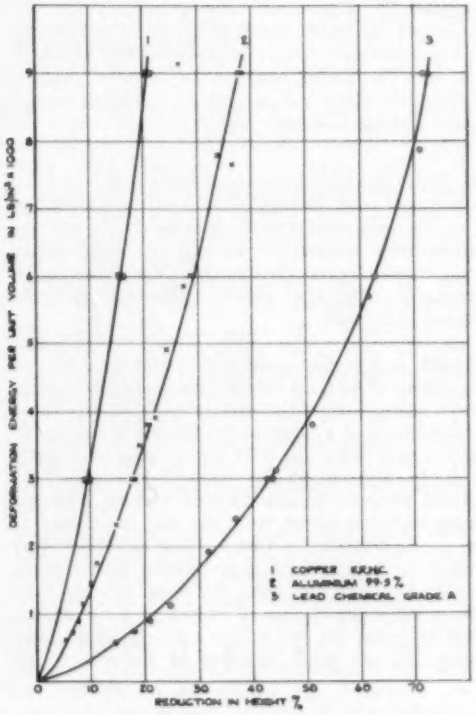
Tests at equal rates of strain. In those cases where there is an appreciable effect, the rate of strain can be made the same in model- and full-scale tests by making the tup-striking velocity proportional to the linear dimensions. This involves making the tup mass also proportional to the linear dimensions in order that the deformation energy per unit volume of material is unchanged. This destroys similarity in the case of the tup and dimensional analysis shows that for valid model tests, inertia forces must in this case be negligible compared with the plastic resistance and the viscous resistance.

Experimental results. Experiments on lead, aluminium and copper conducted under both sets of conditions in turn, *i.e.* equal tup velocities and equal strain rates, showed that the deformation produced in specimens of a range of shapes was the same for model- and full-scale tests for a linear size range of 2 : 1. Typical results obtained for copper deformed between parallel platens without lubricant under repeated blows from the tup are shown in fig. 1. Differences in values which occurred were within the limits of the experimental scatter band. It may be concluded from the equal velocity tests that a variation in rate of strain of 2 : 1 at this level of strain did not produce a sufficiently large change in the yield strength of material to be



3 *Impact forging stress required to deform specimen*

significant in the present tests. This result is in general agreement with the known effect of rate of strain on the yield strength of metals. Other tests at equal velocities on Plasticine, whose yield strength is markedly affected by rate of strain, gave significantly different curves for the two sizes of test. The equal velocity and equal strain rate results show that both the viscous resistance and inertia forces are small compared with the plastic resistance of metals deformed in drop-hammer tests at room temperature.


DEFORMATION ENERGY PER UNIT VOLUME IN LB/IN² × 1000
REDUCTION IN HEIGHT %
1 COPPER ERME
2 ALUMINIUM 99·5%
3 LEAD CHEMICAL GRADE A

4 ABOVE *Deformation of cylindrical specimen by a single blow at a mean strain rate of* 50 *sec.*$^{-1}$

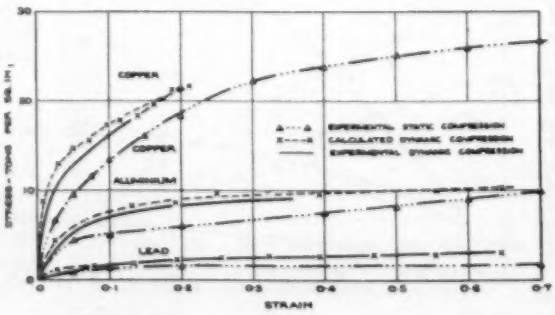
Instrumentation of drop hammer

Drop-forging tests were carried out in a small forging hammer using tups of up to 550 lb. weight and heights of drop of up to 10 ft. The specimens were deformed in a sub-press designed to ensure that the ends of the deforming specimen were kept parallel. To make a systematic study of the process the drop hammer was instrumented. The impact load and reduction in height of the specimens were measured by two capacity-type gauges and the results recorded as a function of time on a C-R recording equipment. The record also included the vertical displacement of the anvil as measured by a seismic pick-up. The height of rebound of the tup could be obtained from a trace made on paper by a pen set in vibration by the impact. The sub-press was set up in the drop hammer and bolted to the anvil. The specimen was inserted through an access hole and arranged axially below the punch. The tup was raised to the required height and the drum camera set in motion and allowed to build up to full speed. A bomb release mechanism holding the tup was triggered and the tup allowed to drop. The impact load, reduction in height and anvil displacement were recorded simultaneously.

The results of tests on 15 lead and 17 aluminium cylindrical specimens, height = diameter = 1 in., under identical conditions showed that the impact forging stress varied by $\pm 11\%$ for lead compared with $\pm 4{\cdot}5\%$ for aluminium. The measured reductions in height were in close agreement with those obtained from the stroke gauge, the variations in each case being $\pm 3\%$ and $\pm 3\frac{1}{2}\%$ respectively.

Deformation in a drop hammer

Earlier work by Tresca,[3] Robin[4] and Ellis[5] indicated that the deformation of metal in a drop hammer was influenced by specimen geometry, temperature, constitution of the metal, tup energy and the number of blows. Further experiments on static compression by Cook and Larke,[6] Polakowski,[1] Tarnovsky,[7] Schroeder and Webster,[8] etc., indi-



5 RIGHT *Dynamic and static compressive stress-strain relationships*

cated that friction profoundly influenced the mode of deformation and it is to be expected that this will also be true of drop forging. From the earlier work partial correlation between some of the related experiments was possible, but the results were far from being comprehensive and further work was clearly essential.

Effect of repeated impact

Results were obtained for the dynamic compressive deformation of lead, aluminium and copper and are shown in fig. 2. It may be seen that the relation between reduction in height and deformation energy per unit volume of specimen differs for each metal. In fact, as will be seen later, these curves are of course directly related to their dynamic stress/strain curves. The figure also shows the results obtained when a given total energy is applied either by a single blow or by two or three blows of equal energy. It may be seen that, particularly in the case of aluminium and copper, the total reduction obtained is only dependent on the total energy and not on the number of blows. There is a slight discrepancy in the case of lead and this is probably due to the greater effect of rate of strain on yield strength in the case of lead.

Effect of specimen geometry

Tests were carried out on lead, aluminium and copper to investigate the effect of size and shape of specimen on the force-reduction curves. The specimens were:

Cylindrical

Dia. (in.) ..	2	3	3	2	1½	1½	1
Length (,,) ..	1	1½	3	2	1½	3	2

Rectangular parallelepipeds

Length (in.)	2	3	3	3	1	1½	1	1½
Width (,,)	1	1½	3	3	2	3	2	3
Height (,,)	1	1½	1½	3	1	1½	2	3

The maximum values of the impact load were obtained from the records and the values of maximum impact forging stress were plotted against reduction in height (fig. 3). It will be seen that over the ranges considered, the impact forging load is independent of size and shape of specimen.

Dynamic stress/strain curves

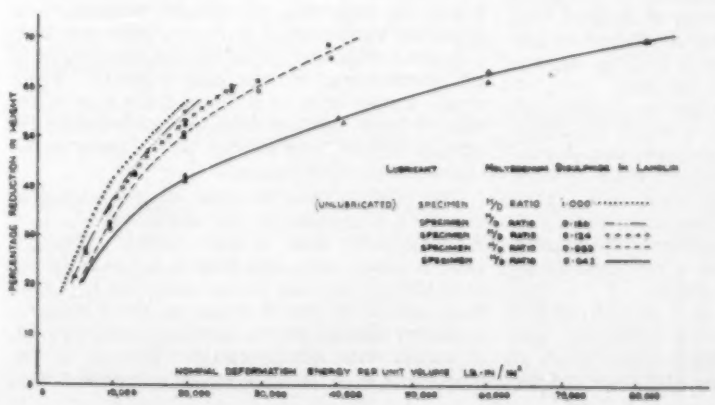
As mentioned above, it is possible to obtain dynamic stress/strain curves from the results of impact tests. Since the dynamic stress/strain curve is dependent on rate of strain, it is necessary in order to obtain a meaningful result to start with impact test results for a constant rate of strain. Accordingly, tests were carried out on cylindrical specimens of lead, aluminium and copper, the height of fall and mass of tup being varied to give results for a range of deformation energy all at a constant rate of strain. The results obtained for an average rate of strain of 50/sec. are shown in fig. 4. In all these tests the loss of energy in rebound was small, being never greater than 6%.

Now it can be shown that the stress σ corresponding to a given strain (reduction in height) e_c may be obtained from the slope of the energy E-reduction curve (fig. 4) at the strain in question:

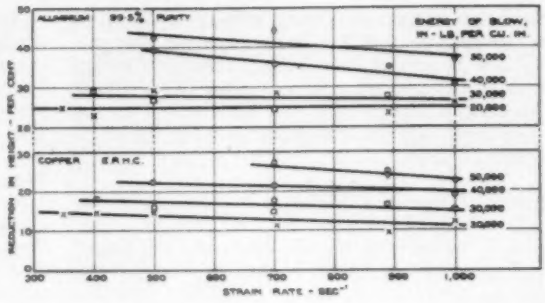
$$\sigma = (1 - e_c)\frac{dE}{de_c}$$

The results obtained by this process are shown by crosses in fig. 5. These values could be verified from the records for impact forging loads up to the onset of oscillations in the load cell record. The measured values of impact forging stress are in reasonably good agreement with the values obtained by differentiation.

The static compression curves for the three materials are also shown in fig. 5 and are in good agreement with results of similar tests by Siebel

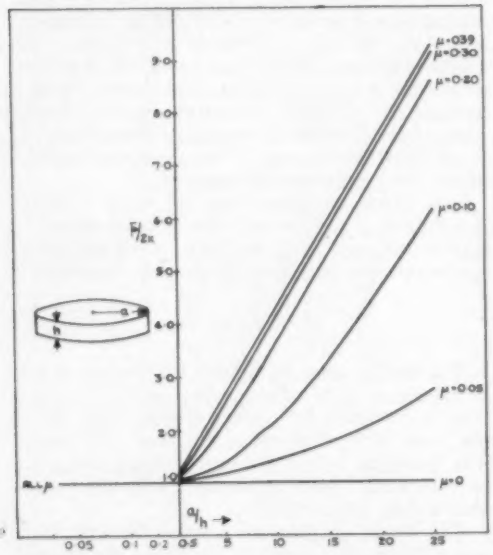

PERCENTAGE REDUCTION IN HEIGHT
NOMINAL DEFORMATION ENERGY PER UNIT VOLUME LB.-IN./IN.³
LUBRICANT MOLYBDENUM DISULPHIDE IN LANOLIN
(UNLUBRICATED) SPECIMEN D/H RATIO 1·000
SPECIMEN D/H RATIO 0·150
SPECIMEN D/H RATIO 0·134
SPECIMEN D/H RATIO 0·050
SPECIMEN D/H RATIO 0·043

6 Deformation energy required to produce a given reduction in aluminium discs



7 RIGHT *Effect of strain rate on the deformation of thin discs of height/diameter ratio* 0·083

8 BELOW *Effect of frictional forces. Typical result for the compression of a cylinder*



and Pomp,[9] Cook and Larke,[6] Alder and Phillips[10] and Loizou and Sims.[11] The results show that for a given rate of strain the increase of dynamic over static stress is in general very dependent on the strain, being, at a strain of 0·2, 15% for copper, 40% for aluminium and 30% for lead.

It may therefore be seen that by a process of integration it will be possible to obtain the deformation energy per unit volume reduction characteristic required for the forging of a metal between parallel platens from the stress/strain curve for the same rate of strain. This last requirement will ensure that the data is appropriate for the process, whether it be carried out in a hydraulic press, mechanical press or a drop hammer.

The above dynamic tests were carried out unlubricated, but comparison of lubricated and unlubricated static tests suggests that friction is relatively unimportant until the height-to-diameter ratio of specimen is small. This is dealt with below.

Impact forging of thin cylindrical specimens

To investigate the effect of friction further, thin discs of copper, aluminium and lead, $1\frac{1}{2}$ in. dia. and h/d ratios of 0·166, 0·124, 0·083 and 0·042, were tested with and without lubrication in the drop hammer. The results for lubricated aluminium are shown in fig. 6, from which it may be seen that for a given deformation energy, the reduction in height decreases slowly at first but then rapidly as the h/d ratio decreases from 0·166. This again shows that friction becomes of increasing importance as the thickness of the disc decreases. In these tests the height of rebound of the tup for a given initial impact energy increases with decrease in h/d ratio, *i.e.* the percentage energy used in deformation decreases rapidly with decrease in h/d ratio.

As confirmation that the decrease in reduction in height and increase in height of tup rebound are due to increase in effect of friction, lubricated specimens were tested under the same conditions (and the results are shown in Table I). The use of lubricants gives a considerable increase in the percentage reduction, the increase becoming progressively more marked as the h/d ratio decreases. The same effect as regards the increased height of tup rebound may be seen from Table II. There would appear to be only minor differences in the effect between different lubricants, although in the case of copper, sulphonated tallow seems to be slightly more advantageous.

The effect of rate of strain on the forging of thin discs of aluminium and copper may be seen from fig. 7 for discs of $h/d = 0{\cdot}083$. Although there is some scatter, the effect is rather small but does show a decrease in the reduction in height with increase in rate of strain, an effect which is consistent with the known increase of yield strength of metals with rate of strain. Because of the presence of large frictional forces, inferences drawn

from these curves should be regarded as tentative. However, the conditions of test are such that the frictional forces can, with the exception of a possible variation in speed, be expected to be constant.

The effect of frictional forces has been investigated theoretically by Bishop[12] for the press forging of a number of shapes. A typical result is shown in fig. 8, for the compression of a cylinder from which it may be seen that when $h/d > 1$ the load is independent of friction, but when $h/d < 1$ the effect of friction rapidly becomes of importance but is asymptotic to a value of $\mu = 0{\cdot}39$. The relatively greater effect of friction on cylinders of smaller h/d is shown in fig. 9 where results for (unlubricated) lead are given for a strain rate of 700 per sec. As the h/d ratio decreases so does the reduction in height for a given deformation energy.

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to be continued

Institute of Metals

AT THE 1960 spring meeting of the Institute of Metals the following awards were made:

The Institute of Metals (Platinum) Medal to Professor Robert Franklin Mehl in recognition of his outstanding contributions to the science of metals and to metallurgical education. (Citation read by Professor J. G. Ball, B.Sc., F.I.M., Member.)

The Rosenhain Medal to Professor Norman James Petch (Professor of Metallurgy, King's College, University of Durham) in recognition of his outstanding contributions in the field of physical metallurgy. (Citation read by Dr. D. McLean, Member.)

The W. H. A. Robertson Medal and Premium to Dr. Maurice Cook, F.I.M., and Mr. E. Swainson, B.Met., for a paper on 'Arc melting of reactive and refractory metals,' published in the *J. Inst. Metals*, 1958-59.

TABLE I *Effect of lubricant on the percentage reduction in height in the impact forging of thin discs (nominal deformation energy per unit volume constant at* 19,500 *lb. in./in.*^{3}*)*

Lubricant	Percentage reduction in height produced in specimens of h/d ratio							
	0·042		0·083		0·124		0·166	
	Al	Cu	Al	Cu	Al	Cu	Al	Cu
Nil	19·7	4·8	33·1	14·4	37·7	20·5	41·7	23·5
Sulphonated tallow	41·7	23·6	48·6	28·4	51·9	30·4	54·4	34·4
Lanolin	42·5	21·5	49·8	26·9	51·7	28·7	54·2	29·6
Graphite in acetone	40·0	21·3	49·2	26·3	54·0	28·0	57·0	29·4
Molybdenum disulphide in alcohol	41·8	19·5	50·4	26·0	51·1	28·0	52·1	29·2
Molybdenum disulphide in lanolin	43·4	20·8	49·8	27·6	52·9	29·5	53·8	30·6

TABLE II *Effect of lubricant on height of tup rebound in the impact forging of thin discs (nominal deformation energy per unit volume constant at* 19,500 *lb. in./in.*^{3}*)*

Lubricant	Ratio of height of rebound/height of fall of tup for specimens of h/d ratio							
	0·042		0·083		0·124		0·166	
	Al	Cu	Al	Cu	Al	Cu	Al	Cu
Nil	0·22	0·36	0·11	0·24	0·08	0·16	0·06	0·14
Sulphonated tallow	0·12	0·21	0·06	0·17	0·05	0·13	0·04	0·08
Lanolin	0·12	0·29	0·06	0·19	0·04	0·15	0·03	0·11
Graphite in acetone	0·14	0·26	0·07	0·16	0·05	0·15	0·04	0·10
Molybdenum disulphide in alcohol	0·13	0·29	0·07	0·19	0·06	0·14	0·04	0·10
Molybdenum disulphide in lanolin	0·13	0·28	0·07	0·17	0·05	0·13	0·03	0·09

NEW FILMS

Liquefied petroleum gases in industry

The important part played in new industrial developments by liquefied petroleum gases is illustrated in a new film produced for Shell-Mex and B.P. Gases Ltd. The film shows from among the many applications of L.P.G., as it is commonly called, examples of its use in a number of factories in different parts of the country. The reasons for its use are also explained. L.P.G. is seen being used for the direct firing of furnaces, as a concentrated flame, and for the creation of a protective atmosphere in a furnace. The storage and distribution of L.P.G. are also described.

In the opening sequences of the film there are views of an oil refinery, and next are seen the specially designed vehicles in which L.P.G. is conveyed throughout the country for direct delivery to a customer's installations. A delivery is made to a medium-sized installation at the Ford Motor Company's works at Dagenham, Essex, where two 10-ton storage vessels have been built to approved specifications.

A smaller unit, a 5-ton Propane storage vessel, is seen at the Bifurcated and Tubular Rivet Company at Aylesbury, Buckinghamshire. Sixty million rivets, of all shapes and sizes, are made at the Aylesbury factory each week and the film shows, among other processes, how Propagas (the brand name for commercial Propane marketed by Shell-Mex and B.P. Gases Ltd.) is used for heating the enamel with which some of the rivets are coated.

At the General Electric Company's Osram glassworks at Wembley, Middlesex, L.P.G. is used as a heat source for the manufacture of glass tubing of all types, ranging from those used for fluorescent lighting to clinical thermometers.

L.P.G. for the production of glassware of the highest quality at the James Powell Whitefriars glassworks was pioneered by Shell-Mex and B.P. Gases. The molten glass is seen being taken from a furnace at this factory to be shaped by craftsmen, the method used for generations. The two burners, as the film shows, produce a constant temperature of up to 1,400°C. and are regulated to feed the correct proportion of air to Propane.

Almost any metal having to undergo heat treatment suffers some degree of deterioration of the surface, due to oxidation, if the heating takes place in air. The film shows how this has been overcome at the Pirelli General Cable Company's factory at Eastleigh, Hampshire, in the production of copper wire.

An oxygen-free exothermic atmosphere is made in a generator, as shown in the film, by the carefully controlled burning of L.P.G. with air in the range of 5–100% of the theoretical air required for combustion. The resulting protective atmosphere, a mixture of nitrogen, hydrogen and carbon dioxide, is fed into the furnace. The wire which passes through the furnace and its protective atmosphere emerges bright and shining.

The Borg-Warner factory at Letchworth, where automatic gearboxes are made, also visited by the camera, has adopted Propagas. The use in the carburizing furnaces, seen in the film, of a gas that is not variable in composition and which does not contain too much sulphur is a necessity if the whole atmosphere of the furnace is not to be impaired and the gears affected. Each batch of gears in the factory is heated for about 2 hours and 40 minutes in the rotating hearth furnaces.

One of the main advantages of L.P.G. is that their principal constituents do not vary in proportion. In a controlled atmosphere, as described at the Borg-Warner factory, the conditions of operation are pre-determined. No variation is required when the generator is running in production, a highly important factor in the case of an endothermic gas used for gas carburizing.

The film shows a furnace with several unusual features at the E.N.V. Engineering Company in Willesden. It is a batch-type sealed quench unit. As an experiment Propane is being used to fire one-half of the furnace. The other half is still using another fuel. After a given period the life of the tubes will be compared. A decision will then be taken whether or not to go over to Propane entirely for the tube firing of the furnace.

Once the furnace has been loaded its operations are pre-set and each change takes place automatically. The carburizing atmosphere is prepared by cracking a mixture of Propane and air at 1,050°C. Propane is used for reasons of purity and because of the consistency of its chemical constituents.

Liquefied Petroleum Gases in Industry was produced for Shell-Mex and B.P. Gases Ltd. by Random Film Productions Ltd. The length is 2,321 ft. (35 mm.) and 928 ft. (16 mm.) and the running time is 25 min. 47 sec.

An industrial notebook on the generation and distribution of electricity

A new Shell-Mex and B.P. Ltd. film, the first of a series of ' Industrial Notebooks,' covers many interesting and diverse aspects of the generation and distribution of electricity in the United Kingdom and the Channel Islands.

It begins with a description of the tiny water-driven alternator which provides the power for the Wiltshire village of Downton, and, in contrast, the following scenes show the massive development of the Loch Sloy hydro-electric scheme with its vast dam which provides power, through the grid, for industrial Scotland. The new steam-powered pulverized fuel station being built on the Thames-side at Northfleet, Kent, is then illustrated. Interesting problems involved in the installation of big power transformers are shown. The care with which they were filled with Shell transformer oil through special filtering and degassing equipment, on the site, was one of them. The transformers were filled with oil on the site because their size and weight made it impossible to carry them by road already loaded with their several tons of insulating oil.

The problem of transporting large equipment for power stations has also been a feature of the construction of the nuclear power station, now in its middle stages, at Bradwell-on-Sea, Essex. The film has shots of the arrival of one of the giant heat exchanger units by sea from Stockton-on-Tees. It is seen being manoeuvred on to a submerged trailer on the shore at Bradwell at high water.

The production of aluminium cable (SCA conductor) for the distribution of electricity is described in the film. The cameras visit a factory at Swansea, where cable is being made. The last stage in this process is the suspension of the aluminium conductor cable in a single span of some 5,000 ft. in length over the River Severn. An interesting sidelight of this work, also shown in the film, is the electrical breakdown testing of the insulators in a high voltage test laboratory.

The film is black and white. It is available in 35 mm. (2,286 ft.) and 16 mm. (914 ft.) gauges, and has a running time of 25 min. *Industrial Notebook* will be obtainable next season on free loan from the Shell-Mex and B.P. Film Library.

Spark machining symposium

Spark erosion for industry

E. W. COOPER

This article is the fifth of a series on spark machining and forms part of the symposium held in Birmingham last September by the NADFS *in collaboration with* METAL TREATMENT. *Mr. Cooper, production development engineer, British Motor Corporation Ltd., outlines the economic possibilities of spark erosion in its applications to the manufacture of small and medium-sized components such as used in the motor car industry*

THE TERM ' INDUSTRY ' covers a multitude of trades, such as coal, gas, electrical, ship building, etc., and where spark erosion can fit into these industries must be decided by people working in them. Industry is taken for the purpose of this paper to cover the manufacture of small or medium-sized components, such as used in the motor car industry.

Since the end of the war a vast amount of capital has been spent in the purchase of machine tools to meet an increasing programme. Not only has the finished car programme gone up, but so also has the amount of scrap material. From the forge 1 ton of scrap for every 1 ton of finished stamping is the case, and from the automatic shop 2 tons of scrap for every ton of finished components. On the average, for every ton of finished motor car produced a ton of scrap material is also produced. Basing this on the cost of steel at £55 per ton, and when sold as scrap at £5 per ton, it is seen that it is costing the British Motor Corporation Ltd. approximately £25 million a year, without allowing for the capital plant required or for the labour charges involved in producing this scrap. The steel producers and the machine tool trade in general have been quite content with this position, and very little effort has been made to improve the ratio of finished components to the amount of scrap produced. Even where development has taken place, progress is slow due to man's inclination to resist change rather than accept and work with it.

Steel producers have been supplying bars of round, square or hexagonal form and leaving it to the users to form this bar into the shapes required by industry. Fortunately perhaps, there are one or two developments coming along quite nicely which will severely challenge this position. Plastics are moving so quickly in development that unless steel producers move rapidly and give us the steel in the right shape at the right price, they may find that steel is no longer a major item, but only a minor one.

Accuracy of dies

The forging industry is a good example of the stagnation that has taken place in our basic industries. This is particularly true when one looks at the smaller firms with old plant and no policy of training technicians for the future. At the present time very little accuracy is put into the manufacture of dies, and even then such accuracy is destroyed when the dies are put into the hammer and set by means of a sledge hammer. By accuracy is meant accuracy as understood by engineers, and not accuracy as set out by the British Standards Institute for the forging industry. It is not at all certain that the word ' forging ' should be used to describe the industry; a better description might be ' mechanized blacksmithing.'

Consider the present method of making irregular shaped forging dies. After the shaping of the outside of the block and the dovetails, the impression is marked out. This is the first source of error. So much depends on what a man considers is correct. His interpretation of the component drawing, his scribed line, can easily be fractions of an inch out and it depends on what happened the night before as to if the centre dots are on the line or on the right- or left-hand side. After marking out the impression is rough milled and again it depends on the operator on how much is left in for finishing. The most diabolical operation of all then takes place, bench finishing. A man, with

the aid of a few tools, proceeds to hack, chip and scratch the metal away until he has something like the finished shape. Any accuracy that might have been put into the previous operations has now, except by chance, been destroyed, and providing that the templates go into the impression, the die is assumed to be right. Whether this die is right to the die drawing, even if the die drawing exists, is not known and if one asks for more than one set of dies for one component, no guarantee can be given except by spending a lot of time and money that the impression will be exactly the same in all dies. The skill and know-how are now on the shop floor, but if the industry is going to make any progress that skill and know-how must be put where it rightly belongs, that is in the design and planning offices.

Die-making by spark erosion

Spark erosion for the manufacture of irregular shaped dies offers a means of ensuring correct form of impression, accurate position, and also repeatability.

Some time ago it was decided to investigate the practical use of spark erosion, as a result of which it is now proposed to go ahead with a full-scale installation. If any one decides to use this process, it is hoped that the experience gained may be of benefit and it is placed at any one's disposal.

On commencing investigations it was realized that there were three types of dies involved: (1) The regular-shaped die; (2) the 'one-off' irregular-shaped die; and (3) the repeated irregular-shaped die. There is no problem in the production of regular-shaped dies, as these can be turned, milled, bored, ground, etc., on conventional machines and can be made to any standard of accuracy that is required.

It soon became apparent that if the spark-erosion process was accepted as the answer to (3), the answer to (2) must be found as well. The whole future of spark erosion depends upon the manufacture of electrodes. If one purchases a capstan lathe, automatic, etc., one can buy these already tooled up to produce the component specified in a given time. The reverse applies in spark erosion. When starting the investigation one could purchase a spark-erosion machine, but the production of electrodes was left to one's own salvation. If spark erosion is to be a complete success, both for the large and small die shop, then the supply of electrodes must be offered as a service just as is the purchase of milling cutters or tipped tools.

1 *Drill jig for drilling the locating and securing holes in the electrode*

It is proposed to deal with the production of repeated irregular-shaped dies first.

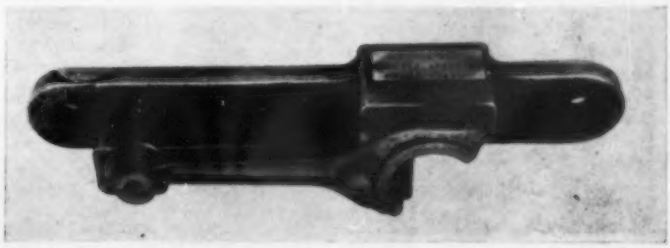
Repeated irregular-shaped dies

One of the biggest production problems is the supply of connecting-rod forging dies, and if one could resolve this it would only leave components such as the crankshaft and camshaft to be dealt with on a development basis. After experimenting with electrodes made from cast aluminium, cold-pressed copper, copper graphite, metal-sprayed brass, metal-sprayed copper, electro-deposited copper and various other materials, it appeared that a hot-forged and cold-set brass electrode would be most suitable, and it was on this type of electrode that development proceeded. At this stage the master dies for the electrode being made by the conventional methods were accepted.

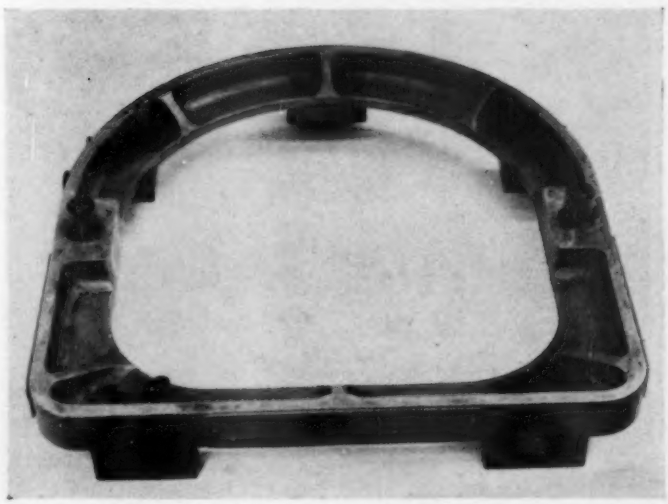
It was also obvious that accurate positioning of the electrode was most important. If the finishing electrode is only a few thousandths of an inch out of line in relation to the roughing electrode, it will put a considerable amount of time on the operation. It was decided to jig drill the locating holes for the electrodes and to make setting-up fixtures. These are illustrated in figs. 1, 2, 3 and 4.

After initial experiments, the conclusion that the spark-erosion machines then on the market were not entirely suitable for general die-sinking work was reached. The filtering arrangements left a lot to be desired, and the machines were small for the type of work in mind. An outline drawing, together with a rough specification, was made and submitted to the trade for quotation. The result is that a prototype machine has been built and demonstrated. The machine is shown in fig. 5 and will be capable of sinking a crankshaft forging die from the solid die block.

The paraffin or dielectric supply is kept separate and where more than one machine is installed a common supply tank is used. The electrical equipment has been kept separate, being housed in a cabinet at the rear of the machine. The advantage is that, as improved or new types of control gear are developed and introduced, the old cabinet can be taken away and a new one installed with a



2 ABOVE *Electrode mounted on holder*



3 LEFT *Fixture for locating electrode holder in relation to die block*

minimum amount of disorganization and at a very low cost. This will enable all users to keep up to date with the latest developments of the spark-erosion process.

Besides accuracy of impression and repeatability, what are the economics of spark erosion?

A connecting rod is critical for both size and weight; it is found that on the average the dies will only stand up for 3,000–4,000 components. Taking the 'A' series engine production at 6,000 per week and 4 connecting rods per engine, this means that 6 sets of dies per week are required. These can be new dies or re-sinks. The prime labour cost of marking out, rough milling, shaping ribs, and bench sinking is £26 17*s.* for a set of dies. To this must be added £10 10*s.* labour charges which takes into account rent of floor space, depreciation of machines, etc. Assuming a 48-week year, the total annual cost of sinking 'A' series connecting-rod dies by existing methods becomes £26 17*s.*+ £10 10*s.*×6×48=£10,756 16*s.*

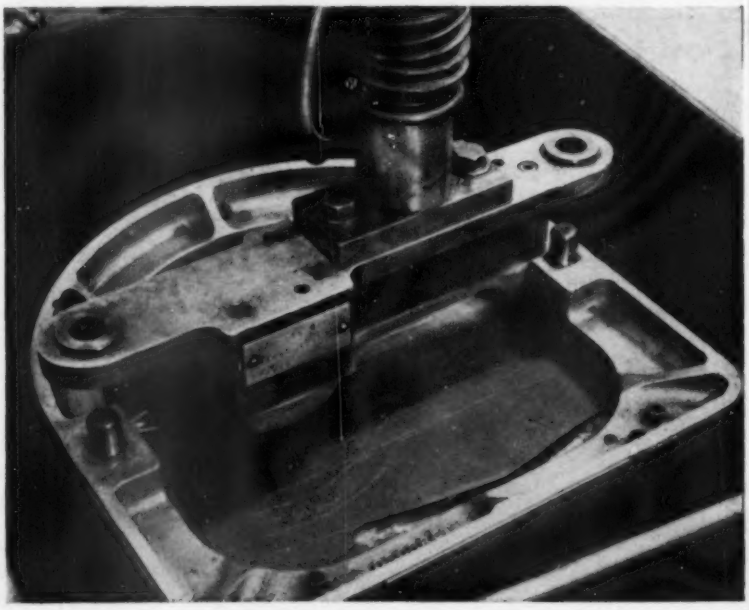
It has been demonstrated that the sinking from the solid by spark erosion of an 'A' series connecting-rod impression can be carried out in 17 hours per set of dies. Thus the total hours required per week for sinking 6 sets of dies=102, and assuming that day shift only is worked with a 40-hour week 2½-spark-erosion machines will be required. If 3 spark-erosion machines are purchased at an estimated cost of £3,500 each, this including the cost of installation, the capital outlay will be: £3,500×3=£10,500.

Basic operating cost will be made up as follows:

	£	*s.*	*d.*
Depreciation, £10,500 at 12½% ..	1,312	10	0
Insurance, £10,500 at 2*s.* 6*d.*% per annum	13	2	6
Repairs and maintenance, £10,500 at 2½%	262	10	0
Dies, jigs, tools, etc.	100	0	0
Indirect material, 700 gal. paraffin	70	0	0
Rent of floor space..	45	0	0
Electricity	102	0	0
Total	1,905	2	6
The direct labour charge will be: 1 man at, say, £15 per week ..	780	0	0
The electrode cost will be 1 electrode per die or 2 per set at approx. 6*s.* each=6*s.*×2×6×48	172	16	0
Yearly cost of producing dies by spark erosion	2,857	18	6
Yearly cost of producing dies by existing methods	10,756	16	0
Yearly saving by using spark erosion	7,898	17	6
Capital outlay for 3 spark-erosion machines	10,500	0	0

Recovery period=69 weeks.

This recovery period could be reduced by running the machines night and day. It is also quite



4 *Locating frame mounted on die block and electrode holder about to be brought down on to the locating pins*

possible for 1 man to run more than the 3 machines allowed for. No allowance has been made for any improvement of products, lessening of management problems, etc. Repeatability is most important. The case can be quoted where the same component was received from two suppliers, necessitating the supply of 2 sets of jigs because of stamping variations.

Only 1 electrode is scrap for each die-sinking operator, although 5 electrodes are actually used. The roughing electrode is the one that is scrap, all other electrodes being moved up one stage on subsequent dies, that is, the finisher on the first die becomes the semi-finisher on the second die, and the semi-rougher on the third die, and so on.

Experience shows that whatever material the electrode is made from, a new electrode must always be used for the final finishing operation. The electrode which is used for roughing must be scrapped, as very little, if any, of the original impression is left.

The solution of the production of electrodes has been quite a long and costly business. Although the spark-erosion process has been under investigation for two years, it is only in the last six months that correct electrodes have been produced and reproduced to a satisfactory standard.

The installation of spark erosion for the sinking of connecting-rod dies will reduce the total time allowed from approx. 50 hours to 17 hours per pair. The pounds will have been saved, and any improvement in electrode wear or cutting rates will only save the pennies.

Fig. 6 shows electrode mounted in position. Fig. 7 shows a pair of completed die inserts.

It has been estimated that to cover 45 components requiring an average of 48 sets of dies per week, 15 spark-erosion machines would be required. As the finishing cut takes the longest time, only 5 machines with 13 kVA. rating would be required for roughing and 10 machines with 4·5 kVA. rating would be required for finishing. The cost of these machines, assuming an average of £3,000 per machine, would be approx. £52,000, including ancillary equipment and installation.

	£
Yearly cost of producing dies by existing methods	59,000
Yearly cost of producing dies by spark erosion	19,000

Recovery period = 65 weeks.

5 *Spark-erosion machine suitable for crankshaft dies*

6 *Electrode mounted in position*

These figures are based on running the machines day and night shift, and assuming that the components will be kept in production for four years without major change.

It will be seen that spark erosion in these cases is an economic proposition, but to be successful the process must be engineered and put down to do a job of work rather than as a plaything to do the unusual.

The machines must be stripped of all unnecessary fittings in order to keep the price to the minimum, and intending purchasers should ask themselves what do they want the machines to do, rather than what can the machines do.

It has been found that the 'fine finish,' as supplied on the standard machines, is not necessary for most types of work, and can be deleted from any new machines that are to be purchased. The 'finishing' cut is the operation that takes the greatest time, and efforts should be made to find the 'roughest' cut acceptable for the work that one is engaged on. Fig. 8 shows a three-impression die, finished by spark erosion for connecting-rod caps.

Fig. 9 shows a Stellited clipping tool which has been finished by spark erosion.

Fig. 10 shows a pair of tungsten carbide die inserts that have been finished by spark erosion. The impression was rough-formed into the carbide before sintering, and approx. 0·010–0·015 in. was left in for finishing. These inserts will be shrunk into die blocks. If this technique is successful, it is intended to try out a connecting-rod die in carbide made by this method.

Present forging procedure is to obtain as many components as possible from a pair of dies and then have a total re-sink of the dies done. In an effort to improve die life the right time to re-sink or touch up dies must be found from actual experience. Before any appreciable wear or damage has taken place the die should be taken from the hammer and the impression cleaned up on the spark eroder. The locating and fitting of the die blocks into the hammer must be engineered so as to avoid breakdown time. If the basic price of the spark-erosion machines is right, the machines could be installed adjacent to the hammers, or in an annexe to the forge, in order to minimize transport.

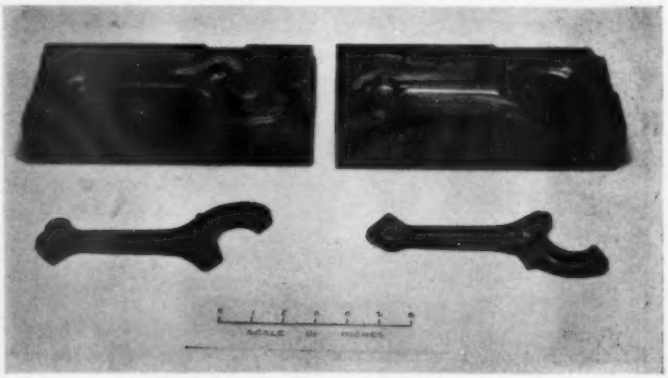
'One-off' irregular die

For the making of the one-off die one is faced with a completely different set of circumstances, and it is considered that a punched-tape control milling machine will be the answer.

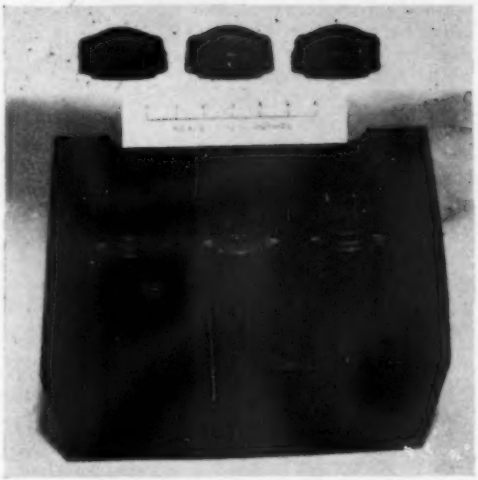
Consideration of the punched-tape control milling machines on the open market led to the conclusion that the price of £12,000–£17,000 for the control equipment was far too expensive, and that the accuracy was greater than required. This may seem a contradiction to previous statements, but it was felt that if one could obtain an accuracy of ±0·003 in. it would be a big step forward from present conditions, and also if one could obtain the control equipment for around the £3,000 mark one could then demand the same accuracy from the supplier. It is unreasonable to ask the small die-shop owner to spend £12,000–£17,000 in addition to the purchase price of a new machine, capital money, for which he has to earn twice as much as he spends.

The vertical-milling machine to be found in every small die shop can be overhauled by the appropriate machine-tool supplier, fitting new lead screws and drive units. To this can be added a simple control cabinet. The complete cost of such a conversion should be around £4,000.

The production of the control-punched tape must be offered as a service to the die industry, so that the firm without the necessary technical staff



7 *Completed die inserts*



8 *Three-impression die*

is able to take advantage of these latest techniques and thus become truly competitive.

Work is proceeding on this project, and it can be confidently expected that it will be resolved in the near future.

Applications of spark erosion

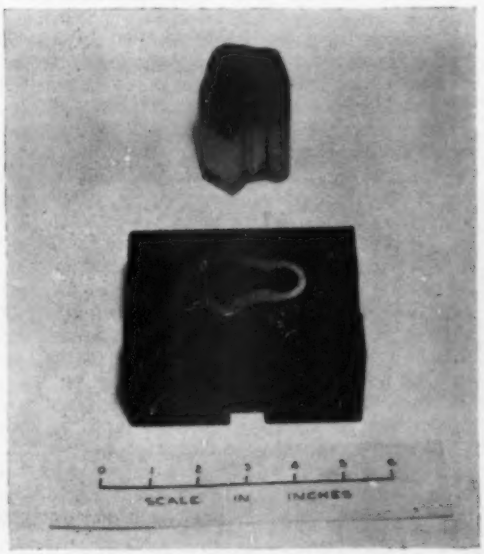
Spark erosion, though in its infancy, can be used in its present form for the sinking of dies. Developments that are taking place now may enable the process or an offshoot of the process to be used in the general machine shop for finishing operations. One has accepted grinding as being the best finish for bearing diameters, but who has asked, is grinding the right finish? Would a finish similar to that produced by spark erosion be better? Research must be carried out on such aspects, and if a spark-erosion finish is acceptable one can visualize production of a very cheap machine, as no stresses and strains are involved thus simplifying design. This will reduce the capital outlay, or if the capital cost is kept the same, enable one to install more plant.

Metal removal operations must be eliminated from the machine shop, leaving sizing and finishing operations only to be carried out. In order to do this the basic industries must be improved, and the emphasis in the future will be on the manufacture of accurate dies and tools. This applies to forging dies, press tools, shell moulds, plastic moulds, die-casting tools, etc., and any process that will give the accuracy required must receive full support.

Many technical papers have been given by people with suitable qualifications on the spark-erosion process. The foregoing is the picture as seen by a layman, from which one can draw the following conclusions:

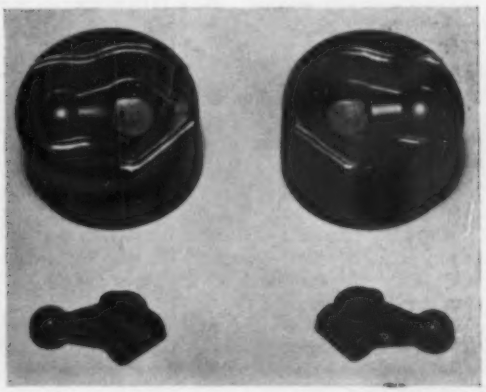
(*a*) The 'know-how' of die manufacture must be transferred to the engineering departments.

(*b*) The manufacture of electrodes must be



9 LEFT *Stellited clipping tool*

10 BELOW *Tungsten carbide die inserts*



offered as a service to enable the small die shop to take advantage of the spark-machining technique.

(*c*) The roughest finish that is acceptable should always be used.

(*d*) The basic price of machines must be kept to a minimum by the supply of compound tables, rotating heads, etc., only being resorted to when the job demands them.

(*e*) Spark erosion can be an economic proposition if it is properly engineered.

SYNOPSIS

Mr. Griffiths (chief production development engineer, British Motor Corporation) introduced Mr. Cooper's paper in the author's absence.

Mr. Griffiths then said that he had just visited the Paris Machine Tool Show. Once again he had found that he was being asked to buy plant to produce the same amount of swarf and waste metal, but at a greater capital investment. In the smaller quantity production machining proposals for capital investment were frightening. The spark-erosion industry had been only very lightly represented.

It was fairly obvious that the pattern of industry as it stood today must undergo a radical change. Emphasis must now be taken off the shaping, finishing and machining shops and put where it ought to be, namely, into the basic processes. The problems involved were considerable and required an entirely new approach. The standards of accuracy, maintenance and repetitivity known in the machine shops must be put into the basic processes.

Mr. Cooper's paper gave a very rough idea of what was involved and the effects which the spark-erosion process would have. In the basic processes three fundamentals had to be achieved. The first was accuracy in the piece of capital plant being used; the second was maintenance of the accuracy in the capital plant; and the third was accuracy in the tooling. This meant that a new approach was needed in the forge.

Die accuracy

The primary problem in the forging industry was to make the first die accurate. At present the industry had no means of making an accurate die. It proceeded, as Mr. Cooper had shown in his paper, to scribe a line on a piece of metal, then to knock the centre pots in it, then to mutilate it on the milling machine and then further to mutilate it by chisels, files, grinding wheels, etc. This governed the standard of accuracy which the industry employed.

The problem of producing the first die, whether it was for the making of an electrode, for cold forming, for the foundry or for the plastic industry, did not come within the purview of the symposium. However, it must be solved. Mr. Griffiths thought that the answer to it and the pattern which it would take were known.

When it came to repetitive dies such as were used in the forging industry, the die must be made so that the first standard with which the maker began continued throughout the life of the product he was making. The bane of the machine shop today was the highly variable product which the drop-forging industry presented to it for usage. Every time the industry made a die to replace a worn-out die the machine shop had to start messing about with its jigs and fixtures. That was because the forging industry had not the means of making its dies uniform at present.

It was in this regard that spark erosion would offer the forging industry something which would enable it to give the machine shops what they required. Because the forging industry used some form of master die in order to produce electrodes, it could always use an electrode which was the same at the end as it was at the beginning. Providing that the electrode was used intelligently, no variation would be experienced. The drop-forging industry must accept spark erosion as a method which would enable its members to give the user of their products the opportunity of having something which was reliable.

Electrode manufacture

The delegates had heard something about the problem of electrodes. Mr. Griffiths said that he had not intended to speak about electrodes, but it was obvious that some method must be evolved of making electrodes repetitively accurate. At Longbridge his company was using hot forging, followed by cold setting. In making a con-rod die this was perfectly accurate and did not lead to any difficulty. It was always the last operation, the finishing cut, which prevented the accuracy. That could always be obtained by using a new electrode for each die made. As the electrode cost only 6*s*., it was only a fraction of a man's time saved per hour.

The emphasis at the Paris Machine Tool Show was on pressed graphite and depositing and not on other ways of making electrodes. Whilst his company had done much work on the depositing of various materials for electrodes, it had not been found to be very successful. Mr. Griffiths said that he intended to put his men back on to it, because if it could be done at the Paris Show as a proposition his company must get down to it in exactly the same way. In that respect the R.R.E. factory at Malvern was doing much work for his company on depositing. His company would continue with the work. As soon as it was resolved it would be passed on to the forging industry.

Mr. Griffiths said that he did not agree with the speaker who had said that it was the user's responsibility. A large organization like the British Motor Corporation might be able to work out its own salvation, but there were many much smaller firms which would not be able to afford the technical staff and experimentation necessary to do this. It would go back on to the shoulders of the machine tool trade.

Mr. Griffiths said that he had emphasized that, because the B.M.C. used about 1,000 tons of forgings a week. Of that 1,000 tons it made only 200 tons. That meant that the B.M.C. had to buy outside four times as many forgings as it made. If it was to maintain the accuracy which it was achieving with its own forgings, it had to help the drop-forging industry to do the same.

As was pointed out in Mr. Cooper's paper, all the data available indicated that spark erosion was sound. The only remaining problem was getting it over to the die-sinking groups. The rate at which it was to be put in must be very carefully evaluated. It had to be a joint effort on the part of many people. B.M.C. was analysing the age of its staff, the retiring rate and many other matters in order to enable the company to install spark erosion without hurting anybody.

Mr. Griffiths emphasized that with the making of the die, the first one-off, with spark erosion and so many other of the new processes now coming into industry, they wanted the machine tool trade to give them in these processes the accuracies which they knew in the machine shop. They wanted the machine tool trade not only to install the machines but also the know-how about the tooling. Mr. Griffiths appealed to them to accept the responsibility and help industry to get through this particularly difficult phase.

DISCUSSION

Mr. D. Joyce (Deritend Drop Forgings Ltd.) said that, as B.M.C. had been doing a fair amount of spark erosion, he would like Mr. Griffiths to answer two questions. First, after eroding the dies were they taken straight to the hammer, or did they go back to the die shop for polishing? Secondly, a die had to be produced to make electrodes. If the electrodes were hot stamped and then cold tapped, that would wear the die faster than anything he knew. That raised the problem that only a certain number of electrodes could be produced from the die before it was worn out. How did B.M.C. overcome that?

Mr. Griffiths, replying to the first question, said that the dies were put straight into the hammer without any work being done on them in the die shop, except for the filing off of the little lumps where the holes were through which the fluid came.

Replying to the second question, Mr. Griffiths said that a con-rod die was a very severe die to deal with. B.M.C. was making thousands of con rods each week in the forge. It was found that for a given size of con rod six electrodes a week were used, making 300 a year. B.M.C. found that it could get two or three thousand brass forgings out of a set of dies. There was, therefore, about a ten-year life in the die as far as the electrodes were concerned.

Mr. R. Ing (Mallory Metallurgical Products Ltd.) asked what Mr. Griffiths's attitude would be to a firm which has satisfied itself that it could use spark erosion? What advice would he offer that firm as to the type of operator it would require? How would Mr. Griffiths install it and cost the work from it? Would Mr. Griffiths tell his audience more about depositing on graphite?

Mr. Griffiths explained that, in referring to the Paris Show, he had stated that there were two emphases on electrodes. One was on a deposit of copper or brass. The other was on pressed graphite.

Dealing with installation, Mr. Griffiths said that Singers at Frome had been working on this for five or six years. They had worked out a technique. Mr. Griffiths had been there, and he thought that they had done an excellent job. They had a not very large room, with the machines down the centre and benches round the outside. They had eight or nine machines and two men in the room. The men ran the machines and built up electrodes. One delegate had mentioned building up electrodes for a pipe joint. Singers built them up like that. They built an electrode up in a composite way with standard turned, milled and drilled parts.

B.M.C. had taken a young die sinker who had finished his time into the department and trained him to do it. He was paid the ordinary die-sinker's rate.

Mr. Deeming (Alfred Herbert Ltd.) said that he was intrigued at Mr. Griffiths's statement that lack of accuracy in the dies caused forgings to be plus or minus $\frac{1}{4}$ in. Many firms possessed copy milling machines which would produce dies to much closer tolerances than that. Apart from that, if the men who had previously made the dies not sufficiently accurate were no longer to make them, they would surely have the job of making the electrodes. How could one expect the electrodes to be any more accurate?

Mr. Griffiths said that perhaps Mr. Deeming had not understood him. His point had been that one must accept the die made for the electrode as the standard at present. Whatever came from the die shop would be the standard. One worked

from that and every one after that would be exactly the same.

Mr. Deeming argued that if they were all the same that was what was needed, not so much the original accuracy.

Mr. Griffiths instanced some of the forgings used by the motor car trade. They had very often to go to two, three or four different people to obtain them. They found that they were having different sizes of stampings coming in, because there was a different time when a new die was put in and a different time when the old die was taken out. There were all the variations in the die between the new die and the old one coming into a works at all sorts of different times. It caused chaos. By spark erosion wherever it was made one could give the same basic electrode.

Mr. Griffiths warned the delegates that hot forging would be severely challenged in the not too distant future by other processes coming along. As long as one had it, one must put into the forge the technique operated in the machine shop. One must be able to take the dies out and put them back to size and keep them as near as possible to size all the time they were in use. They should not be put in, worn to a certain point and then taken out and some new ones sunk. This meant that the hammers and everything else had to be right. The top must be right in relation to the bottom. A method must be devised of setting the top and bottom die accurately in relation to one another. When a die showed signs of wear, one must be able to take it out, spark-erode it and replace it. One should be able to get it back to size. This introduced into the forge something which they did not know at present, but it was known in machine shops throughout the world.

Dr. H. Obrig (Aachen Technical University, Germany) asked if Mr. Griffiths had carried out any investigations designed at comparing the die life of spark-eroded and normal machined con-rod dies?

Mr. Griffiths said that B.M.C. had found that they were about the same. The spark-eroded die might show a slight improvement on die life, but not much. If the touching up business could be engineered, it would probably be found that the die life would go up by as much as three times.

The Chairman said that he understood that the die life would go up as much as three times because, during the life of one die, it would be taken out and corrected by spark machining.

Mr. Griffiths agreed.

The Chairman said that that was quite a variation on what one would regard at present as die life. This was a die which had been rectified twice, before being discarded. It was a material variation from the drop-forging trade's conception of die life, because it involved intermediate work.

Mr. F. J. Jones (Forgings & Presswork Ltd.) said that he fully agreed with Mr. Griffiths on re-planing dies by erosion in as much as it affected depths. He had tried this and discovered that as soon as a die showed any wear in its lengths or widths a standard electrode would not touch it unless a disproportionate amount was taken off the top. How much did Mr. Griffiths consider was a re-dressing?

Mr. Griffiths said that they did not know enough about it yet, because the hammers were not accurate enough to allow the system to be operated. The die was taken out with a sledge hammer. For that and other reasons they had not been able to do it. Their investigations had shown that, if they took the graft in the die out sufficiently quickly, it would enable them to re-touch it up and get it back into the hammer in an hour.

Mr. B. Kennedy (Firth-Derihon Stampings Ltd.) asked Mr. Griffiths to give a little more information on how he formed the location on the electrodes and how he adapted them to the electrode machines.

Mr. Griffiths said that the example in the paper of the con rod illustrated fairly clearly what was done. There were two types of forgings. One was the regular-shaped forging, which was very easy. It could all be machined by the orthodox method. It could be done to a thou. The location points could be made very exact. The second was an irregular-shaped die, where one was working off the form. With the con rod they sometimes used a plastic die. The electrode was dropped into it, a cap was brought over and locating holes were drilled and re-moulded, which could always come back again off the jig on the end of the spindle. It must be realized that if a die was put on a milling machine for marking out it would be miles out, because it was not accurate. One had to work from accurate location points with die sinking if one was going to use a milling machine of a definite face. It was best to cut the milling right out and to work from the solid wherever possible, because one related electrode and holder in relation to the die properly every time. One came back again to the same datum line. This technique was understood completely in the machine shop and no trouble was experienced. That technique must be put into the forge.

The Chairman reminded the delegates of figs. 1 to 4 in Mr. Cooper's paper.

Mr. Elvins (Garringtons Ltd.) said that his company was producing possibly 5,000 rods in a shift from one machine. He did not feel that it was practical to talk about having the dies out at sufficiently regular intervals in order to maintain a

sufficiently constant volume in the impressions. Replying to a question from Mr. Griffiths, Mr. Elvins said that, properly engineered, it should take about a quarter of an hour to take a die out.

Mr. Griffiths said it should take two to five minutes.

Mr. Elvins said that there were four dies to take out.

Mr. Griffiths said that all that was necessary was to pick it up and put a new one in. The techniques known in the machine shops must be introduced into the forge. He was in a plant in America and saw a man operating some type of boring machine. He saw another man come along with a bar underneath his arm, speak to the machine operator, take one part off the machine, take the new part from underneath his arm and on to the machine, and walk away with the old part underneath his arm. That was what was understood by tool changing in the machine shop. It was merely a matter of proper bolster design and proper maintenance of the top and must be introduced into the forge.

A delegate regretted that Mr. Cooper had talked about the one-off irregular die at the beginning but had very rapidly passed on towards the end of his paper without giving much useful information. Many delegates were very much involved with the one-off die. Forging electrodes for this was obviously not a practical proposition. Mr. Cooper had mentioned tape-controlled milling machines. What were Mr. Griffiths's personal views on the use of tape-controlled milling machines, possibly for producing a master from which electrodes could be made for one-off die sinking?

Mr. Griffiths said that this was an interesting question. He saw industry in the future involving processes which would require matching dies. Matching dies could not in any circumstances be made with any degree of accuracy by the present methods of making dies. The B.M.C. had done a great deal of work to find whether the accuracy and skill from the shop floor could be put into an engineering office, so that it could be properly engineered in just the same way as it was engineered in the machine shop.

Mr. F. C. Bird (Walter Somers Ltd.) said that he would like to offer a few comments on matters which had arisen during the discussion. It occurred to him that the price of copying machinery and electronic controls would affect the production of dies by ordinary means, namely, by cutting the metal away, but was not likely to affect to so great an extent the production of dies by spark erosion. It was at least conceivable that master dies for the production of electrodes by spark erosion could be produced at some central joint plant where electronic control equipment, too expensive for the smaller drop forger, could justifiably be purchased. If electronically-controlled machines had to be employed for conventional die production, that was surely an argument in favour of the alternative of spark erosion?

Turning to the size of forgings and tolerances, Mr. Bird said that he could not see how that affected spark erosion. One would assume that the object of a drop forger, having certain tolerances laid down, was to produce a die which would give a forging initially close to the lower tolerance, and the die would be used until it was worn to the maximum tolerance. If the die was produced by conventional machining, there must be some amount of error in the die. To the extent that it existed it meant that the life of the die was impaired.

Accuracy was entirely dependent upon the economics of how much time one could afford to spend on the die. It was an economic proposition to spend more time upon a master die for producing electrodes and get it to a tolerance which would be unnecessary if it was concerned only with a one-off instead of producing up to 200 electrodes. Accuracy therefore may be bound up with the method of electrode production, casting shrinkage, etc.

Mr. Bird said that a most valuable contribution had been made by the delegate who had suggested that by the use of a zinc-tin alloy, which was a two-phase alloy with a solidification range as distinct from a solidification temperature, in the same fashion as plumbers' solder, it would be possible to press such a composition and in effect obviate the shrinkage losses, in which case the accuracy of the electrode would be exactly that of the master die. If the master die was to be used only for relatively low melting-point alloys which were themselves in a semi-plastic state, he would not expect them to wear very rapidly. In short, the production with care, time and cost of a single master die would ensure automatically a similar accuracy for every electrode produced from it. The lower the temperature of the metal used, provided that it was otherwise satisfactory, the lower would be the pressure required to squeeze it into the intricacies of the die impression, the longer would the die last and the more one could afford to spend upon it in producing the master die.

All this had no relevance to the issue of forgings sent out. It was a question of the tolerance stipulated and how long the working die was permitted to exist in the stamps. If the machining experts could state, as they could, the extent of the gap which must be permitted to ensure an acceptable finish upon an eroded die surface, all that had to be done was to allow that gap, whether it was half a thou or a thou or a thou and a half, and there was no reason why an accurately produced electrode should not result from an accurately produced die.

Press quenching

Automatic control at Ford's

QUENCHING OF STEEL PARTS emerging from a furnace must be very carefully supervised in cases where distortion is not permitted. Even when the work-piece is clamped in a press and quenched by a flow of oil, it is important to start the quench at the right temperature and continue it at the correct rate; this will ensure that the best metallurgical and physical properties are maintained, and distortion avoided.

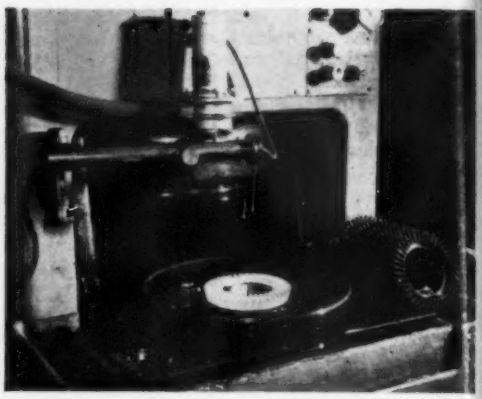
An example of such work occurs in the heat treatment of crown wheels and other gear parts at the Ford Motor Company Ltd., Dagenham, where control of the quenching action on 12 Gleason machines is now performed automatically by electronic controllers, using a Radiamatic detector as the primary sensing element.

The instruments used are ElectroniK controllers supplied by Honeywell Controls Ltd., and the primary sensing element is their Radiamatic compensated radiation detector. Use of the Radiamatic method on this type of quench press has now, in fact, been standardized by the Ford Motor Company.

Heat Treatment is carried out in twin track furnaces supplied by International Furnace Equipment Co. Ltd. These furnaces are themselves controlled by Honeywell instrumentation and additionally incorporate the Protectoglo flame failure alarm system on the gas curtain controls.

The radiation detection system was at first experimentally tried out for measuring the product temperature only, but the presses now also have their full operating cycle started off automatically by means of these instruments when the correct temperature for quenching is reached.

The detectors in this installation are fitted vertically on the upper part of the machine. The lens of the detector focuses radiant energy from the work-piece on to a radial assembly of thermocouples connected in series. The smallness and quick response of this assembly make it a very exact means of appreciating temperatures and faithfully converting them to an electrical voltage that can be measured by a distant instrument. This method of detection is ideal in conditions such as this where vibration, shock, high speed of process and high temperature preclude the use of normal thermocouples.



Gear wheel in a Gleason quench press. The Honeywell Radiamatic pyrometer is seen above the workpiece

Temperature curve

A distant controller instrument is associated with each detector. The controllers are continuous balance instruments, having circular clear vision scales which give a non-permanent indication of temperature at the detector head. Immediately the work-piece is placed in the machine, the instrument begins responding to the voltage from the detector and the scale reading rises to about 1,550°F (850°C.), where it meets the descending temperature of the work-piece which emerged from the furnace at approximately 1,610°F.; the scale reading falls with the cooling of the work-piece until approximately 1,510°F.; a contact in the instrument then causes the work-piece to be horizontally moved and the whole machine cycle begins.

Built into the control circuit is an element to prevent the press operating if a gear is inserted at below the quenching temperature.

Continuous principle

The ElectroniK instrument itself operates on the potentiometer principle, the voltage from the Radiamatic being received across a slide wire and compared with a standard voltage; the difference in the voltage is conveyed through an amplifier system to a motor which moves the slide wire contact and places the circuit in balance again. At the same time the scale is made to rotate. This is a continuous procedure, and in the present application it goes on until a pre-determined point is reached when cams behind the circular scale operate a mercury switch contact which indirectly causes the machine to clamp and the first oil inlet valve to open. The accuracy of this measurement is exceptionally good. The instrument calibration is within 0·25% of scale span.

Bell furnaces

General characteristics of three types of bell furnaces were discussed by L. W. Johnson, Industrial Heating Dept., General Electric Co., Shelbyville, Ind., U.S.A., in 'Metal Progress,' March, 1960. The following are the chief points discussed by Mr. L. W. Johnson

INCREASINGLY stringent requirements for heat treating and brazing cycles pose complex equipment problems for aircraft and missile makers. Sizes and shapes of parts to be brazed or heat treated vary over a tremendous range. Complicating the problem in the development phase, particularly, the work must often be done in existing furnaces because of insufficient time to purchase and install new furnaces.

For these reasons the versatile bell furnace is very popular. Minimum fixturing is required when brazing because the work does not have to be moved during the brazing cycle. Furthermore, the bell furnace normally can accommodate a wide variety of sizes and shapes of work, a wide variety of heating and cooling cycles, and a wide variety of atmospheres.

Factors that affect versatility are: size, maximum temperature rating, temperature uniformity, maximum heating rates, maximum cooling rates, and atmospheres (including vacuum) that can be used.

One type of furnace now coming into prominence because of high-temperature requirements is the cold-retort furnace. A major heat barrier exists in furnaces used for treating components for high-speed aircraft and missiles. Many of the processes involved in the manufacture of high-speed aircraft and missiles must be done either in vacuum or in a carefully controlled atmosphere. Since minute quantities of moisture or an improper gas can ruin the work, it must be enclosed in a tightly sealed container. Normal practice has been to place the work in a sealed retort. Then the retort is put in a furnace, or the furnace is placed over the retort. For long heating cycles at relatively low temperatures this is acceptable. However, for higher temperatures and shorter cycles this hot retort becomes a serious impediment.

The cold retort furnace removes this heat barrier. However, because of their relatively high initial cost, some people who should be using radiation shield furnaces are not using them. Actually, a radiation shield furnace may be a sound investment for operations in the 1,150–1,250°C. range. Furthermore, if higher temperatures are anticipated, the radiation shield furnace is a 'must.'

In this furnace the outer walls become the retort while the heating units are inside with the work. A series of radiation shields or baffles is placed between the heating elements and the outer wall to cut down on heat losses. This type of furnace, of course, has higher heat losses than a conventional brick-insulated furnace, but it gives some very real advantages.

First of all, we eliminate the hot retort which is a replacement item. Though the cost of replacements can be controlled by limiting the maximum operating temperature, using care in furnace operation and retort handling, careful selection of retort materials and design, and regular and careful retort maintenance, retorts must still be recognized as expendable parts. Provisions must therefore be made for maintenance and replacement, and spares must be available.

On the other hand, the life of all components in the radiation shield furnace should be excellent if the furnace is used at or below its rated temperature. The cold walls act as the retort to contain the protective atmosphere or vacuum. The radiation shields are subject to very little stress except from thermo cycling. Since they are broken up into a number of small sheets, the cumulative effect of thermo cycling is minimized. Heating units are molybdenum rods which are rated as high as 1,650°C., and are now being applied at higher temperatures. The load grids are the only hot metal which must withstand any appreciable loading.

Heat barrier removed

Secondly, we have eliminated the heat barrier between the work and the source of heat or cooling. In the hot retort, heating and cooling rates are definitely limited by the rate at which heat can be transferred through the retort. Though the slow cooling rates (particularly below 540°C.) can partially be compensated for by using multiple bases and retorts with a single heating furnace and by using a forced convection cooling bell, it is difficult to get the cooling rates normally desired when working with high-temperature metals. There is little that can be done about the slow heating rates except to use a proportioning control (rather than an off-on control) so that the retort is maintained at maximum allowable temperature throughout the heating cycle.

In the radiation shield furnace there is no barrier between the heating units and the work. Since the molybdenum rod heating units can be operated as high as 1,650°C., substantial heat head between the heat source and the work is possible. Heating units are in the same protective atmosphere as the work; therefore, molybdenum (ortantalum, or tungsten) heating units which can operate at high

heat densities and still retain their physical strength can be used. With these metals the furnace can have a heat rating of two or three times the rating possible with heating elements which operate in air.

In a radiation shield furnace rapid cooling rates can be provided by a cooling system which allows rapid circulation of an inert atmosphere. The walls through which the cooling gas must be introduced are cold, so vacuum-tight piping connections are relatively easy to make and maintain.

In a hot retort furnace, with its brick-lined heating chamber, the total mass to be heated, other than the work, is normally rather high. The radiation shield furnace has no hot retort which must be heated, and insulating shields are made as thin as possible to reduce the effects of thermo cycling. Therefore, the total furnace mass to be heated, or cooled, is very low compared to a retort-type furnace. This allows the furnace to be heated or cooled very rapidly.

Economics also important

A radiation shield furnace equipped for 1,230°C. operation, but suitable for modification to 1,430°C. operation, with a vacuum system capable of evacuating to 1/10 micron in about 30 min., will cost about double the price of a hot retort furnace suitable for operation at 1,180°C. with a hydrogen atmosphere and equipped with two bases and two retorts. In most installations a single radiation shield furnace should be able to do as much work as a hot retort furnace with two bases and retorts. Thus, much less floor space would be needed.

The shorter heating cycle and the lower furnace mass of the radiation shield furnace will be overbalanced by the higher wall losses. Therefore, the energy costs will probably be about twice as high.

However, a radiation shield furnace will need less atmosphere gas.

The radiation shield furnace will require substantially less expenditure for replacement costs.

TABLE I *Bell furnaces for heat treating and brazing above* 1,040°C.

	Refractory pier base	Metal dome	Radiation shield
Maximum temperature rating	1,120–1,260°C.	1,120–1,260°C.	1,260–1,430°C. and higher
Temperature uniformity	Fair (*a*)	Excellent	Excellent
Speed of heating to uniform temperature	'Thermal inertia' of base slows uniform heating of load	Low thermal inertia and low losses of dome base allow rapid, uniform heating	Low thermal inertia of supports allows rapid, uniform heating
	Hot retort forms barrier between work and heating units—slows heating rate		High heating rates can be achieved
	Though speed of heating may be slow, it may be doubled by using molybdenum heating elements		Molybdenum heating units standard
	Brick-lined heating bell heats and cools slowly. This is usually used to advantage by maintaining heating bell hot and removing from load for cooling		Furnace can be heated and cooled rapidly. More power is required for heating
Maximum cooling rates	Hot retort forms barrier between work and cooling medium in normal operation		Furnace and load cool rapidly when power is shut off
	Thermal inertia of refractory pier slows cooling		Because a cold outer wall forms the 'retort,' it is relatively easy to circulate a cooling gas through the furnace or introduce a coolant such as liquid carbon dioxide
	Seal (*b*) (normally sand or welded seal) is located in heated zone near work	Seal (*c*) (metal-to-rubber gasket) is located outside of heating zone well below work	
Atmospheres (hydrogen, helium, argon)	Being used successfully	Satisfactory	Atmospheres can be used at low pressures
Vacuum purge ..	Sand seal not satisfactory; welded retort satisfactory	Satisfactory	Normal
Vacuum operation ..	Not normally built for vacuum operation	Retort seal is satisfactory for vacuum operation	Normal
First cost	Basic design is lowest first cost	Basically only slightly more expensive than refractory pier furnace	Most expensive because of large vacuum system and expensive high-temperature metals used

(*a*) High 'thermal inertia' of refractory base makes the bottom heat and cool more slowly than the higher portion of the load.

(*b*) With forced-convection cooling, the seal projects near the work area and disrupts cooling flow patterns. A sand seal does not allow liquid spray cooling, and a welded seal would have to be carefully prepared to withstand liquid spray quenching. Coolants must be introduced and removed through pipes welded to the retort bottom. These welds do not last many cycles.

(*c*) With forced-convection cooling, streamlined air flow around the retort can be obtained. Metal-to-rubber seal allows liquid spray cooling. Coolants such as liquid carbon dioxide can be used inside the retort.

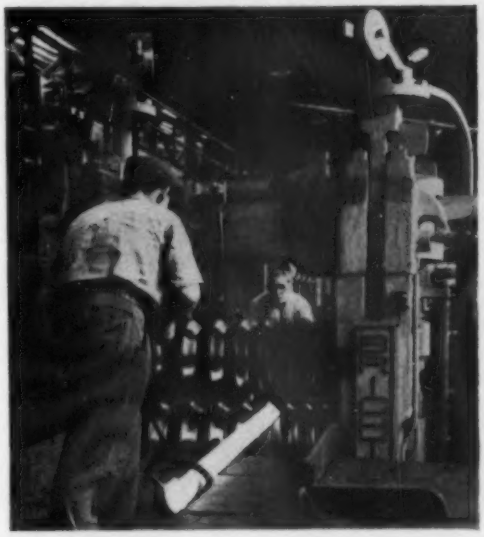
Twenty-five years of stainless steel

SILVER JUBILEE of Firth-Vickers Stainless Steels Ltd. is being celebrated this year. History of the company is to a great extent the history of stainless steel, and some part of it was told by the chairman, Dr. C. Sykes, F.R.S., at a luncheon to mark the 25th anniversary held in Sheffield's Cutlers' Hall last month.

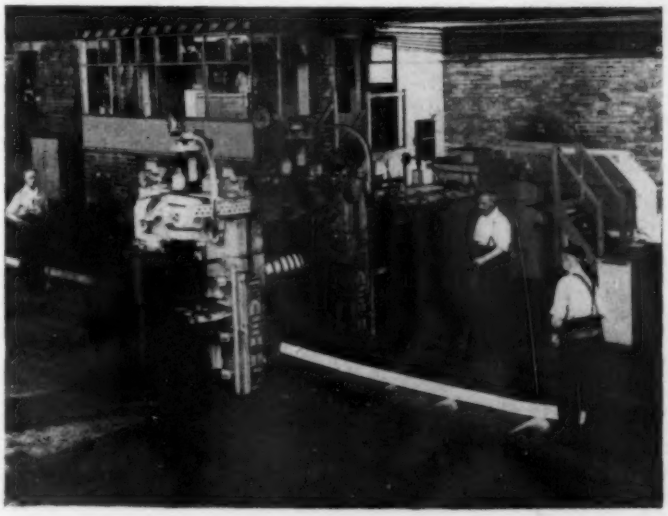
It is generally agreed that Harry Brearley was the man who first exploited the corrosion-resisting properties of the straight chrome steels in the form of cutlery. He did this in conjunction with some of the cutlery firms in Sheffield, and this business began to gather momentum immediately after the first world war.

Simultaneously, metallurgists all over the world began to investigate the whole range of more highly alloyed chrome steels, with the result that towards the end of the 1920s many of the austenitic steels had been developed, and their potential uses for a wide variety of corrosion-resisting and heat-resisting purposes were being worked out. The first major chemical plant in austenitic steel in this country was constructed by Imperial Chemical Industries Ltd. in 1926. It had to be riveted, because at that time welding techniques were not reliable.

Up to about 1930, Firth's being the pioneers, had the lion's share of this developing business. Other steel firms saw the prospects in this trade and were not idle. In particular, the English Steel Corporation Ltd., as it is now, had done a good deal of development work and was producing a series of stainless and heat-resisting steels. Conditions in the steel trade were bad, and Firth's and Brown's amalgamated their steelmaking interests;



ABOVE *Rolling a billet in the* 18-*in. finishing mill*



LEFT *Overall view of the* 18-*in. cogging mill at the Staybrite rod and bar works of Firth-Vickers Stainless Steels Ltd.*

Cammell Laird's and Vickers' steelmaking interests were joined in the English Steel Corporation.

The management of these companies must have had quite a problem to solve—here was a new and exciting business with tremendous possibilities. How could it be developed with the steel trade as a whole practically bankrupt? In the event, they decided to merge their interests in rolled stainless products and castings, and Firth-Vickers was formed.

Dr. Sykes told how the business has grown since that early merger. In its first year of operation, 1935, Firth-Vickers' deliveries were just under 6,000 tons and it has 1,400 employees. Today, manufacturing capacity is 40,000 tons per annum and 4,200 people are employed.

Soon after the company had been formed, the special-steel industry became occupied with developments for the second world war and it was in this period that the company developed its centrispinning techniques, which made an important contribution both to the sleeve valve engine and the jet engine and has now many ordinary commercial applications. It provided, too, discs and blades for the early Whittle engines, large quantities of bar for aero engine valves and tank welding rods, and a great variety of special steels for the Admiralty.

In 1944 the output had increased to 20,300 tons. In 1945 and 1946 there was a drop to 11,000 tons, since many of the special steels developed for war purposes found no great demand in peacetime.

'It was in this depressing period that Mr. Holmstrom, our late managing director, began to apply persistent and convincing arguments as to the tremendous future ahead for stainless steel, not only in the chemical and dairy industries, but in the domestic field and in automobiles,' said Dr. Sykes. 'It became clear that for the future we ought to abandon our traditional methods of sheet production and go over to production in the form of wide strip both on the score of cost and quality.'

This meant that an entirely new site was necessary. Firth-Vickers bought a site at Shepcote Lane, Sheffield, in 1946 and construction started in 1948. Here again outside events shaped the arrangements for Shepcote Lane Rolling Mills. At the time the expansion scheme was being worked out, the steel industry was scheduled for nationalization. Samuel Fox had ideas for a similar scheme. There was said to be an insufficient supply of dollars to cover duplication of certain equipment required from the United States and so Shepcote Lane Rolling Mills went ahead, with Firth-Vickers having two-thirds of the share capital and Samuel Fox & Co. one-third. They have the same shares in the output.

Dr. Sykes relates that the original Shepcote Lane scheme started at an estimated cost of £875,000 and finished at just under £3,000,000. The first mill turned round in 1952 and the plant finally got into its stride in 1954. Apart from the acute inflation which took place during this period, the costs increased because the scheme became more ambitious as time went on. The cold mills were designed to produce sheets equivalent to 15,000 ingot tons, but the hot mill capacity as installed was 100,000 tons. In 1948, when the final decision on this item was taken, the total ingot equivalent for all types of stainless steel products produced in the whole country was only 70,000 tons. The idea behind having such a large capacity hot mill was simply that the company could increase output capacity merely by adding cold mills and descaling lines. Part way through the construction, the present managing director, Mr. T. Dewar, persuaded the board to modify the layout so that it could at some future date, if so desired, incorporate the Steckel principle, using hot boxes, and thus increase the length and weight of the hot rolled coils.

Steckel plant installed

By 1954, when the plant was working to planned capacity, although the output of sheets was 50% higher than the original planned figure, it was clear that capacity was inadequate. It was decided to proceed with the installation of the Steckel plant at the main Shepcote Lane plant, to install a new 12-in. strip mill with an annual output of 4,000 tons of strip, and to replace the bulk of the old bar mills by modern mills, with a 50% increase in capacity.

By the middle of 1959 it was found that yet more sheet and strip capacity was needed. Towards the end of last year a new scheme was put forward for a further increase in capacity at Shepcote Lane. The expansion will cost £2,000,000 and is already under construction. It is expected to be in operation, producing mainly stainless steel wide strip in coil, by the second half of 1961. At present the mills are producing 400 tons a week of stainless steel coil up to 40 in. wide, and the new expansion will nearly double this output.

In line with the increase in the production capacity, Firth-Vickers is also expanding its warehousing and processing plant sections to cope with the increase. The main additions to the mills will consist of a second 42-in. Sendzimir cold-rolling mill and a fourth softening and descaling line, together with extensions and modifications to existing ancillary plant, as well as the installation of an extra coil build-up line and a new furnace for softening ferritic steels.

NEWS

Individual pumping system

APART FROM THE DESIGN and development of vacuum furnaces, a great deal of work is carried out each year by our metallurgical research laboratory of Edwards High Vacuum Ltd. to provide suitable pumping systems for metallurgical work. Different metals and different processes such as melting, degassing, brazing and annealing may not require the same ultimate vacuum and the quantities of gas evolved also affects the type of vacuum pump used.

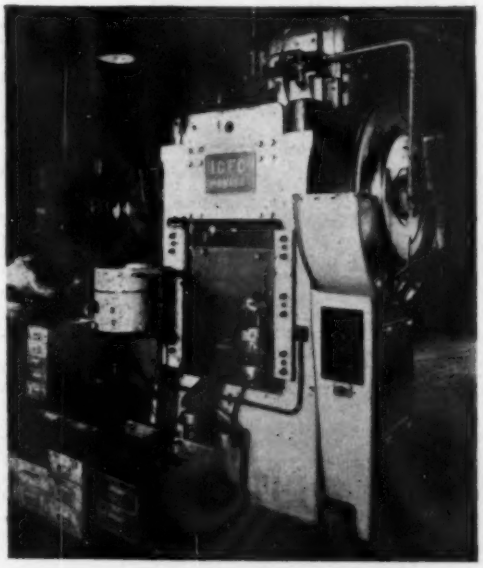
A good example of such a pumping system was supplied recently to Atomic Power Constructions Ltd. for use in their laboratories at Hounslow, Middlesex. The pumps were fitted to a Royce Electric forced air circulation furnace, the equipment being used for vacuum annealing and stress relief in connection with their fuel development programme. It was necessary for the furnace tube to be removed from the furnace after heating, but still maintained under high vacuum for a period. The water-cooled T-piece which connects the pumping system to the furnace was therefore equipped with quarter swing butterfly plate valve so that the vacuum could be sealed. The whole T-piece, including the butterfly valve, could then be disconnected from the pumping system and the furnace tube removed, the vacuum being sealed by the butterfly valve in the closed position.

The annealing furnace is a standard Royce Electric forced air circulation furnace complete with a fully automatic temperature control and temperature recording equipment. The maximum temperature at which the furnace operates is 400°C., with a rating of 24 kW. for a 440-volt, 3-phase, 50 cycles supply. The internal dimensions of the furnace tube are 9 in. dia. by 50 in. high. The tube was supplied complete with a top flange machined to mate with the connecting flange of the 'Speedivac' pumping equipment.

The pumping system consisted of a Model 903B oil diffusion pump having a peak speed of 1,500 litres/sec. and an ultimate vacuum of 5 by 10^{-6} torr, backed by a Model 1SC450 single-stage air-ballasted rotary pump. The diffusion pump is fitted with 12R8 right-angle baffle valve which also serves to isolate the pump from the furnace system. A 6-in. bore water-cooled T-piece is provided to form a demountable connection between the baffle valve and the furnace tube. A QSB6 quarter swing butterfly valve is used to seal the vacuum in the T-piece when it is disconnected from the pumping system. The furnace tube and the T-piece can thus be removed from the furnace without breaking the vacuum in the tube itself.

Vacuum measurement is provided by a combined Pirani/Penning vacuum gauge, the control unit being panel mounted on the side of the pumping unit. The Penning gauge head is mounted in the water-cooled T-piece to indicate the vacuum in the furnace tube, while Pirani gauge heads are mounted in the backing line to indicate rough pressure. Hand-operated 'Speedivalves' are used in the backing and by-pass pumping lines.

A 300-ton press for cold forging steel designed by Cold Forging Ltd. The press is equipped with a multiple stage tool for making nuts direct from steel bar stock at speeds of up to 4,800 nuts/h.



Cold forging firm's developments

Camp Bird Ltd. announce important developments in connection with their steel cold forging process.

Long-term loans totalling £500,000 have been given under the auspices of the Saar Government to a new company, Saarlaendische Werkzeug- und Maschinenfabrik W. Nothelfer GmbH, in which Camp Bird hold 80% of the equity. This company will manufacture cold forged products and the machine tools and other equipment needed in steel cold forging. Ten acres of building land and several houses for key workers have been sold at nominal cost to the company by the municipality of Lockweiler, near Saarbrücken, where the factory is to be built. The foundation stone will be laid on May 8, 1960, by the Saar Minister for Economics. Production is scheduled to begin before the end of the year.

This is the first time that a German state has subsidized a British-controlled company, and the innovation will be watched with much interest, as the possible precursor to other such ventures. The new Saar company will be under the joint direction of Walther Nothelfer, managing director of A. Nothelfer & Soehne, machine and press tool manufacturers, of Ravensburg (Camp Bird has a 51% controlling interest in this company), and Dr. Heinz Feldmann, technical director of Cold Forging Ltd. (a wholly-owned Camp Bird subsidiary).

Lockweiler will be the third plant for the manufacture of steel cold forged products to be established under the aegis of Camp Bird. Cold Forging Ltd. now have 16 presses and related equipment at Sunbury-on-Thames. The Camp Bird associate company, International Cold Forging Corporation, have started production of steel cold forgings for the French motor, electrical and plumbing industries at Le Vulcain, Monaco. Production at Sunbury-on-Thames is primarily for the British motor, electrical and pipe fitting industries, although export

orders for the company's cold forged steel unions are now being received.

Camp Bird also announce the acquisition of a 49% interest in Caltexa Trust (Registered), owners of the world rights of the cold forging process. Previously, Camp Bird have held only the British Commonwealth rights. As part of the new agreement, the Camp Bird group will enjoy sole selling rights for the equipment, designed and controlled by Caltexa, used in the cold forging process.

An associate company (American Cold Forging Inc.) has been set up in the United States, and negotiations are in an advanced stage for licensing the cold forging process or embarking on joint ventures with United States and Canadian industrial concerns.

Equipment specially designed for the cold forging process by the group includes mechanical cold forging presses of 300 and 800 tons rating; hydraulic cold forging presses of 1,000 to 2,000 tons rating; fully automatic steel bar-cutting machines taking up to 3-in. dia. bar stock; phosphating installations of ½ ton to 1 ton capacity; atmosphere-controlled heat-treatment plants for annealing products and tools; a multiple stage nut-making tool and press based on cold forging practice. This equipment is now being manufactured under the group trade name 'Colforg,' and will be seen by the public for the first time when a complete cold forging installation in operation will be exhibited at the Hanover Machine Tool Exhibition in September. Prototypes of this equipment were designed and made at the Monaco, Sunbury and Ravensburg plants of the group. Machines are now being manufactured at Ravensburg, and production orders have also been placed on a leading British press manufacturer for machines to be sold in the United Kingdom. Complete cold forging installations are planned to be available for sale during 1961.

In conjunction with the proposed Saarland plant, it is proposed to build a study centre for steel cold forging at Lockweiler. A complete course in the practice of cold forging will be given to purchasers of the group cold forging equipment at this study centre, which will be under the direction of Dr. Feldmann. Courses will be held alternatively in English, French and German. The first courses are scheduled for spring, 1961.

Iron and Steel Institute

The Council of the Iron and Steel Institute made the award of the following medals and prizes at the annual general meeting this month:

Bessemer Gold Medal for 1960 to Professor Dr. Hermann Schenck, director of the Institut für Eisenhüttenwesen, Rheinische-Westfälische Technische Hochschule, Aachen, Germany, and president of the Verein deutscher Eisenhüttenleute.

Sir Robert Hadfield Medal for 1960 to Dr. J. C. Hudson, head of the Corrosion Section, Chemistry Department, British Iron and Steel Research Association.

Andrew Carnegie Silver Medal for 1959 to Dr. P. R. V. Evans, Research Department, formerly Metropolitan-Vickers Electrical Co. Ltd., Manchester, for a paper on 'The effect of rolling unstable austenitic 0·76% carbon steel at 220–300°C.'; his co-author, Professor Hugh O'Neill, was not eligible for an award.

Williams Prize for 1959 to Mr. I. M. D. Halliday, Research and Development Department, the United Steel Companies Ltd., Rotherham, for a paper on 'Continuous casting at Barrow.'

Open days at the National Engineering Laboratory

The National Engineering Laboratory is to hold Open Days on June 15 and 16, 1960, when the laboratory will be open for inspection. Special displays have been arranged, including many items developed since the last Open Days in 1958. Facilities for sponsored investigations for industry will be on show, as well as results of work carried out as part of NEL's general programme of basic and applied research. These include the automatic measurement of errors in machine tools, the development of hydrostatic transmissions, research on the cold extrusion of steel, studies of the performance of high-speed bearings, investigations of the growth of fatigue cracks, and the preparation of new international steam tables.

Representatives of any organization with engineering interests will be welcome. Applications for invitations, stating which day is preferred, should be sent to the director, National Engineering Laboratory, East Kilbride, Glasgow.

The Incandescent Group has made the announcement that the London office telephone number has been changed from SLOane 7803 to BELgravia 7803-5. The address, 16 Grosvenor Place, London, S.W.1, remains unaltered.

Sandvik to build factory in India

Sandvik Steel Works, Sandviken, Sweden, have been granted a licence to build a factory in India at Poona, about 150 miles east of Bombay. Both tungsten-carbide bits and finished products will be produced and the total investment in land, buildings and machines is estimated at £550,000.

An Indian company, Sandvik Asia Ltd., will be formed to take charge of the planned production. The project will be financed by both Swedish and Indian capital. Mr. Dharamsey M. Khatau, a well-known Indian industrialist, will be a member of the new company's board.

Production will start in 1961 and initially the factory will be under the leadership of Swedish engineers, who will introduce Swedish production methods. A staff of Indian technicians will be trained gradually.

European Federation of Corrosion

The British Association of Corrosion Engineers has been elected a member of the European Federation of Corrosion. The object of the Federation, which is a non-profit-making union, is to promote European co-operation in the field of research on corrosion and methods of combating it for the benefit of the community at large. Membership of the Federation is restricted to non-profit-making European technical and scientific societies whose activities are connected with the field of corrosion or the protection of materials.

The Federation seeks to achieve its objects by convening joint European meetings for the discussion of subjects of general interest; by convening meetings of working parties for the discussion of specific problems; by the creation of working groups for investigating special problems; by the organization of study trips; and by other means. The general secretariat of the Federation is managed jointly by the Dechema in Frankfurt a.M. and the Société de Chimie Industrielle in Paris.

The British Association of Corrosion Engineers was formed last year generally to promote the dissemination of technical information about corrosion matters; to develop the free interchange of information among members; and to promote such educational and other facilities as may be required for the establishment of corrosion engineering as a recognized profession. Individual membership (£2 2*s*. a year) is open to everyone interested and associated with corrosion engineering. The address of the hon. secretary is 97 Old Brompton Road, London, S.W.7.

PEOPLE

Admiral Sir Michael M. Denny, G.C.B., C.B.E., D.S.O., has been appointed a director of English Steel Corporation Ltd.

The following appointments have been made in respect of wholly-owned subsidiary companies of English Steel Corporation Ltd.:

Mr. W. D. Pugh as chairman of English Steel Forge and Engineering Corporation Ltd., English Steel Rolling Mills Corporation Ltd., English Steel Castings Corporation Ltd., English Steel Spring Corporation Ltd., and Taylor Bros. & Co. Ltd.

Mr. W. E. A. Redfearn as managing director of English Steel Forge and Engineering Corporation Ltd.

Mr. R. G. H. Taylor as chairman of English Steel Export Corporation Ltd.

Mr. G. Craven, D.S.C., as managing director of English Steel Export Corporation Ltd.

In the English Steel Forge and Engineering Corporation Ltd. **Mr. R. W. Brocklehurst,** director, becomes general superintendent; **Mr. E. Levesley,** at present manager, becomes superintendent of the Forge Machine Shops; and **Mr. R. J. H. Hunt,** at present manager, becomes superintendent of the Heavy Forge.

Mr. C. J. Beavis has been appointed by Birlec-Efco (Melting) Ltd. to take charge of all Birlefco's smelting activities.

Formerly works engineer for the Distillers Co. Ltd. at their factory near Port Talbot in South Wales, Mr. Beavis was responsible for all engineering construction and maintenance required for the production of calcium carbide.

Dr. R. L. P. Berry, beryllium project manager since 1958, has been appointed to the board of I.C.I. Metals Division.

Joining the Research Department of the Division in 1936, Dr. Berry spent the war years in the Royal Engineers and the next five at Birmingham University, where he graduated and later carried out post-graduate work on behalf of I.C.I. in the School of Metallurgy.

Since he resumed full-time service with I.C.I. Metals Division in 1951, Dr. Berry has been primarily concerned with the development of ' new ' metals, notably titanium and beryllium. In 1958 he was appointed project manager in charge of the construction and commissioning of the I.C.I. beryllium plant, which came into operation towards the end of 1959.

Dr. Berry, who is 41, has also been appointed to the delegate boards of two I.C.I. subsidiary companies, Marston Excelsior Ltd. and Lightning Fasteners Ltd.

Mr. E. P. Collins, advertising manager of the Morgan Crucible Co. Ltd. and its associate companies, has recently been elected hon. secretary of the Incorporated Advertising Managers' Association.

Mr. W. F. Cartwright has taken over from Mr. William Barr as president of the Iron and Steel Institute for 1960-61.

William Frederick Cartwright was born in 1906 and educated at the Dragon School, Oxford, and at Rugby. His technical training began in 1925, when he entered the Swindon works of the Great Western Railway. He joined Guest Keen and Nettlefolds Ltd. in 1928 at their Dowlais Works; in 1931 he was appointed assistant works manager at the Port Talbot Works of Guest Keen Baldwins Iron and Steel Co. Ltd. Four years later he became technical assistant to the managing director, a position he held until 1940. During this period he was intimately concerned with the reconstruction and enlargement of the company's East Moors Works. He was appointed chief engineer in 1940, and at the same time elected to the board of the company; three years later he became general manager of the Margam and Port Talbot Works.

Mr. W. F. Cartwright

When the Steel Company of Wales Ltd. was formed in 1949, Mr. Cartwright was elected a director and became general manager of the Steel Division. It was under his leadership that the development of the Abbey Works at Port Talbot was carried out. In 1954 he became assistant managing director of the company.

A member of the Institute since 1936, Mr. Cartwright was the first chairman of the Engineering Committee following its establishment in 1946. He was elected a member of Council in the same year, and became a vice-president in 1955. He was awarded the Institute's highest honour, the Bessemer Gold Medal, in 1958.

Mr. Peter Wrightson, O.B.E., managing director of Head Wrightson & Co. Ltd. since 1955, has been appointed vice-chairman and managing director.

Mr. Percy Rowley, B.SC., F.I.M., has resigned from the boards of Smith's Stamping Works (Coventry) Ltd. and its subsidiary, Smith-Clayton Forge Ltd., on attaining the age of 70, and after 44 years' service with the company.

Mr. A. Geoffrey Banks has been elected president of the Engineering Centre, Birmingham, in succession to **Mr. Victor Brenner,** who has held the office for the past four years.

Mr. Banks is a director of Johnsons Iron & Steel Co. Ltd. and Johnsons Rolls Ltd. He has been a member of the Committee of the Engineering Centre for six years.

Wickman announce the appointment of **Mr. C. F. Watts** as a director of the company. Mr. Watts, who is a Fellow of the Institute of Chartered Accountants, joined the company in 1945, was appointed secretary and later financial controller.

Mr. Ivon A. Bailey has been appointed deputy chairman of the Mond Nickel Co. Ltd. and of Henry Wiggin & Co. Ltd., and **Mr. Edward Vaughan** has been appointed a director of both companies.

NEW PLANT

Quenzine quench oils

Quenching oils containing Quenzine—a formulation of wetting oils and other ingredients developed in the U.S.A. by Aldridge Industrial Oils Inc.—are now being made in this country and marketed by the Electric Resistance Furnace Co. Ltd. The oils are claimed to give greater hardness to oil-hardening steels; to give a deeper case quicker and with minimum distortion, oxidation and sludging. In the initial and intermediate temperature range they have very much increased cooling power, but below 370° C. the cooling rate reduces rapidly to permit gradual transition to martensite, thus combining maximum hardness with minimum distortion, strain and cracking. They are particularly economical to use, showing little if any deterioration over long periods of hard usage and, due to their lighter viscosity compared with other quenching oils, draining more freely from the work.

Quenzine, once mixed, becomes an integral part of the quench oil and will not separate. It has no preferential dragout, it contains no soaps or fats and is not affected by filters. Quenzine does not hold water but allows moisture to settle and to be drained off from the bottom of the tank.

New finishing machine

A very recent development, 'vibratory finishing,' has great advantages over conventional barrel finishing. Much work and research has been done in America, and the Hepburn Conveyor Co. Ltd., Rosa Works, Wakefield, has recently concluded an arrangement with the Pangborn Corporation of America to undertake the manufacture of machines in this country.

The Pangborn machine has advantages over any other system in having provision for varying amplitude and varying frequency, enabling a large range of work to be undertaken at greatly increased production rates.

Speeds of from 10 to 100 times greater than tumbling barrels are achieved. Less media and compounds are used for any given amount of work. The visual operation of the process is possible during operation. The machine is suitable either for severe cut-down (0·025 in. of stock has been removed from stainless steel forgings and castings in 30 min.) or for delicate work (lamination 0·006 in. thick, 4 in. dia., have been deburred and finished without distortion).

This new system makes possible the processing of interiors and shielded surfaces which are unsuitable for barrel cleaning, and will carry out cleaning, descaling, deburring, radiusing, fine finishing, colouring, burnishing and ball burnishing.

Machines are being made in capacities of 1½, 3, 6, 12 and 18 cu. ft., and the company are prepared to undertake the supply of a complete process plant, compounds and media in addition to the vibratory finish machine. Manufacturers are invited to submit samples for processing without obligation.

Scanning electron-probe X-ray microanalyser

A powerful method of qualitative and quantitative metallurgical analysis is provided by the technique, originally developed in France by R. Castaing, of irradiating a minute area of the surface of a metallic sample with a fine-focus beam of electrons, and analysing the resulting emission of X-rays excited in the sample.

This type of analysis differs from most others because of its non-destructiveness and its ability accurately to detect minute local differences in composition. It is, therefore, a useful research technique for examining the detailed structure of metals and alloys.

An important feature of the microanalyser, manufactured by the Cambridge Instrument Co. Ltd., is the incorporation of a deflection system in the electron microscope so that the electron beam can scan the surface of the sample. The instrument is not, therefore, restricted to point by point microanalyses, but can also produce X-ray images showing, in turn, the distribution of selected elements over the area scanned. The X-ray image is displayed on one of two cathode ray tubes. The other tube simultaneously displays a reflection electron image of the same area so that a direct visual comparison between the surface topography of the specimen and the distribution of a selected element can easily be made.

The instrument described was designed by Dr. D. A. Melford and colleagues at the Tube Investments Research Laboratories with the co-operation of Dr. V. E. Cosslett and Dr. P. Duncumb, who were responsible for the first model developed in the Cavendish Laboratory.

Bright platinum plating

The development of platinum plating has been limited to the difficulties associated with conventional plating baths. Johnson Matthey & Co. Ltd. have now made available a stable platinum plating solution from which bright, heavy and coherent deposits may be obtained. This bath, known as DNS platinum plating solution, is based on the complex sulphato-dinitrito-platinous acid, $H_2Pt(NO_2)_2SO_4$, and patent applications covering electrolytes of this type have been filed in a number of countries.

The bath is acidic, and may therefore be used successfully on electrical components and on printed circuits. Platinum from DNS solution can be deposited directly on to copper, brass, silver, nickel, aluminium and titanium. For deposition on tin, zinc, cadmium or steel an undercoat of silver or nickel is necessary.

Deposits from the new bath are exceptionally bright and lustrous at all thicknesses, and no polishing is required. Electrographic tests have shown no evidence of porosity in deposits up to 0·001 in. in thickness on polished copper. Above this thickness some slight evidence of cracking may be observed. Microhardness tests on deposits give values of 400 to 450 VPN.

Radiation protective screen

In anticipation of the need for protection of personnel using radioactive materials in industry foreshadowed in the Draft Special Regulations recently issued by H.M. Stationery Office, the Premise Engineering Company, The Crescent, Abbots Langley, near Watford, Herts., has produced a simple form of lead-protected screen for industrial use.

Based on experience gained in the production of lead-protected X-ray equipment for hospitals over the past ten years, this screen is comparatively light and strong and freely mobile. It measures 3 ft. wide and 6 ft. high and has a lead glass window 9 in. by 6 in. The supporting frame is of welded steel tube, braced and carried on ball-bearing castors. The screen, constructed from resin-bonded plywood and lead sheet, is fitted within

continued on page 30

Electrical Aids in Industry *Data Sheet* **No. 11**

Dielectric Heating - 2

The ability of dielectric heating to generate heat through the mass of a suitable material provides the following considerable advantages over other heating methods.

1. A body of uniform section and composition is heated uniformly throughout. Hence there is no waiting for heat to be conducted to the centre of the body, and this is of particular advantage when the body is thick, and, as is often the case with dielectric materials, has poor heat-conducting properties.

2. The rate of heating can be faster than by external heating methods.

3. Since there is no external heat source, overheating or burning of the surface of a heat-sensitive material is avoided.

4. Heat input and heating time can be positively controlled.

5. High thermal efficiency is achieved.

6. Production can start immediately after switching on, and no current is used, nor heat lost, during periods of shut-down.

7. Vastly increased productivity is obtainable with less labour (usually unskilled), and fewer machines and less floor space are required.

8. Dielectric heating provides flexibility of layout and can be inserted directly in the production line.

Dielectric Heating: typical application data

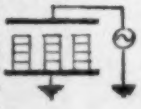
Typical application	Frequency	Radio frequency power
Thermoplastic welding.	30-100 Mc.p.s.	Up to 1 kW
Plastic preheating, wood glueing.	10-40 Mc.p.s.	2-30 kW
Plywood manufacture.	2-10 Mc.p.s.	Above 30 kW

Note: 1 Mc.p.s. = 1,000,000 cycles per second.

A few of the industrial applications of dielectric heating are briefly described below.

Preheating Thermosetting Plastics

Dielectric heating is ideal for preheating pellets used for thermosetting plastic mouldings, which are poor heat conductors. It promotes faster curing, reduces moulding time and can increase production 10 to 15 times. Tool wear and damage to metal inserts are reduced, and thicker sections can be moulded.



Welding of Thermoplastic Materials

An important and extensive application of dielectric heating is the welding of thermoplastic sheets in the fabrication of such commonly used articles as raincoats, hoods, handbags, pouches and packaging materials. Dielectric heating is the only method which can usefully be employed, since the heating electrodes, and hence the outside sheet surfaces, remain cool while the inside surfaces forming the joint are fused, and a perfect weld results.

Two or more thermoplastic sheets are welded under pressure from electrodes suitably shaped to the area of weld required, the current being switched on at the same time as pressure is applied, and off when the weld is completed and the pressure released. Stitching is thus eliminated and a far stronger joint achieved.

In some cases, a suitably profiled electrode can be fitted with a knife edge to cut the sheets immediately outside the weld line, welding and pattern-cutting being thereby carried out in the one operation. Dielectric welding can be applied also to very large thermoplastic products such as linings for swimming pools, and cinema screens.

Drying

Drying of materials by dielectric heating has the great advantage that the material tends to dry out from the centre, the reverse of what happens when external heating methods are employed, and the risk of overdrying and overheating of the surface is eliminated. While the removal of large amounts of water from inexpensive commodities may sometimes be uneconomical, dielectric heating in the production line often leads to a higher overall production efficiency. It is valuable for removing final moisture traces and becomes increasingly economical as the value of heat-sensitivity of the commodity increases.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available — "Induction and Dielectric Heating" is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

6736-4

New plant

concluded from page 216

the tubular steel frame to give protection to the edges. The window has a lead equivalent equal to the lead sheet and is positioned to give an adequate view of the subject. The screen is finished in matt black and the frame in aluminium, but white or coloured screens can be supplied.

Where a limited view of the subject is acceptable a system of reflecting mirrors is provided instead of the window and the subject is seen on a clear glass screen.

Soluble cutting oils

Shell-Mex and B.P. Ltd. are now marketing a range of improved soluble cutting oils—Shell Dromus Soluble Cutting Oils.

These reformulated grades contain an improved coupling agent to facilitate the formation of a stable emulsion when the oil is mixed with cold water, hard or soft, with the result that the oils do not now possess the odour of disinfectant normally associated with soluble cutting oils. This makes them more acceptable, particularly to women operators. In addition, the absence of the conventional phenolic coupling agent reduces the tendency of the emulsion to cause irritation of tender skins.

The use of a non-phenolic coupling agent introduced certain manufacturing problems which required the development of new techniques and the construction of special blending plant before they could be overcome successfully. The new techniques required were first developed in the laboratory and new plant was then designed to meet these requirements and to produce the new soluble oils under the most efficient and hygienic conditions.

Shell-Mex and B.P. have now erected several of these new plants, adequate to meet all demands and to give economical and rapid delivery throughout the United Kingdom.

These improved grades possess the same high stability and anti-corrosion properties of the original grades. The range includes soluble oils which make emulsions suitable for the widest possible range of machining operations.

Elcontrol developments

Following a very successful trading year in 1959, in which total output increased by approximately 30% over 1958, Elcontrol Ltd. announces the following items of interest regarding future developments:

A factory extension has just been completed to its works at Hitchin, which provides substantially increased machine-shop facilities and at the same time enables much needed expansion to take place in the electronic assembly departments.

A new Special-Products Division has been formed which brings under one control the design, production and application development sections for dealing with customers' individual requirements. This step has been made necessary by the rapidly increasing demand from industry for tailor-made control schemes in wide variety. Many projects of this type involve the design and supply of complete control systems for new production machines and plants, and it is felt that this trend will continue strongly in the next few years.

Classified Advertisements

FIFTEEN WORDS 7*s.* 6*d.* (minimum charge) and 4*d.* per word thereafter. Box number 2*s.* 6*d.* including postage of replies. Situations Wanted 2*d.* per word.

Replies addressed to Box Numbers are to be sent, clearly marked, to Metal Treatment and Drop Forging, John Adam House, John Adam Street, London, W.C.2.

MACHINERY FOR SALE

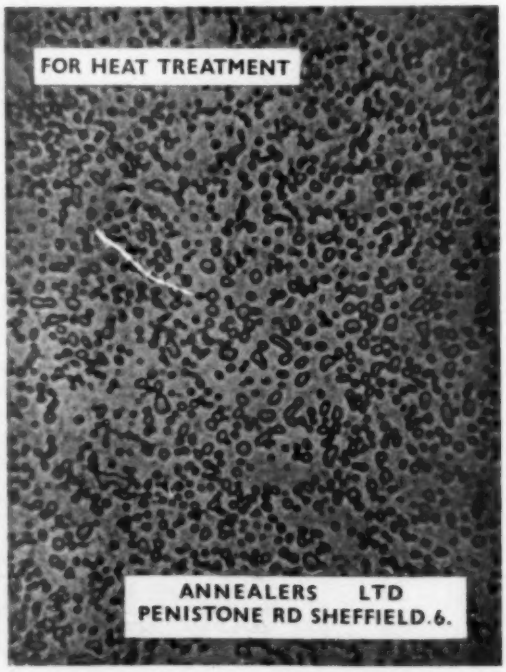
KAMPF FK 2A COPY MILLING MACHINE, Pantograph 1¼—4 to 1, direct copying at 1 to 1. £1,500.—Hopkins Bros. (B'ham) Ltd., Lifford Lane, Birmingham 30.

SAMUEL PLATT 800-LB. MOTORIZED FRICTION BOARD DROP HAMMER for sale. Length of drop 5 ft., between uprights 14 in., size of anvil 17 in. x 31½ in. Electrical equipment for 400/440/3/50. Weight about 10 tons.—F. J. Edwards Ltd., 359 Euston Road, London, N.W.1, or 41 Water Street, Birmingham 3.

TWO FULLY AUTOMATIC 1,000-LB. CHAMBERSBURG BOARD HAMMERS, together with one spare head unused. One machine worked 18 months, the other two years. Offered with two Etchells thermostatically controlled oil-fired furnaces, new nine months ago. Available July/August. BOX TF 129, METAL TREATMENT AND DROP FORGING.

SERVICES OFFERED

REFRACTORY BRICKSETTER, 20 years' experience, will undertake repairs or complete rebuilding of all types of heat-treatment furnaces. Lancs. area.—Box RB 130, METAL TREATMENT AND DROP FORGING.



IN QUENCHING

Let our experience be your guide

The engineer *must* have the right quenching media for that particular steel or non-ferrous alloy. He can obtain expert advice on the most suitable product for the job by contacting our Technical Sales Representative, or by writing or phoning us direct.

We have a wealth of experience in solving these problems and offer a selection of Quenching Oils and Salts to meet every day-to-day requirement over a wide temperature range. Evco Quenching products are most economical in use, because they give consistently satisfactory results.

A new publication on Quenching Media is now going to press. If you could usefully do with a copy when published, please write *now*, on your business heading.

It's the 'know-how' on quenching that means success. Uniformity—Stability—Speed.

Edgar Vaughan & Co. Ltd.

LEGGE STREET, BIRMINGHAM, 4

INTERNATIONAL MACHINE TOOL EXHIBITION 1960
STAND 604 EMPIRE HALL 2nd FLOOR
Olympia · London June 25-July 8

Works and depots at: Birmingham, Manchester, Liverpool, London (Southall), Bristol, Glasgow

In association with the Houghton group of companies all over the world

ENV

facilities

for

HEAT TREATMENT

The ENV heat treatment plant is one of the most modern and comprehensively equipped in the London area. Facilities include full metallurgical control, quenching press equipment and electrically controlled flame hardening machine.
Enquiries for heat treatment of production quantities are invited.

E.N.V. ENGINEERING CO. LTD
Hythe Road, Willesden, N.W.10
Telephone: LADbroke 3622

AP 113

Grad

COLLOIDAL GRAPHITE PROVES ITS WORTH

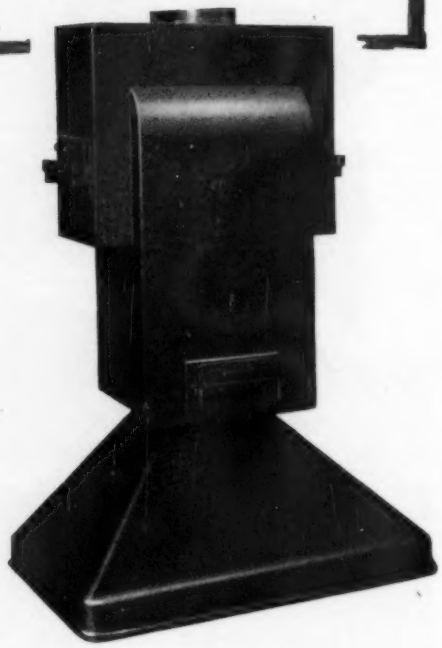
In one recent case where a customer was using a well-known brand of colloidal graphite in water, and had been doing so for many years, trials with our famous "Grad" colloidal graphite in water proved so successful that die life was nearly trebled.

The customer immediately changed over to using "Grad" and the overall production of this particular item, which is a precision forging, was practically doubled. The saving in cost is enormous!—and it's CLEANER TO USE.

GRAPHOIDAL DEVELOPMENTS LTD.
CONSULTING LUBRICATION ENGINEERS
CLUBGARDENS WALK, SHEFFIELD, 11
Telephone: Sheffield 27385

Dust & Grit Collectors

A new addition to the range of A. & O. dust and grit collectors



This photograph shows an Alldays & Onions UF/1 Dust Collector, primarily for use with hearths and designed to meet the requirements of the Clean Air Act.

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The picture shows Mellopad laid in a pit preparatory to casting the concrete block for a precision grinder, capacity 24 ft. x 18" dia.

Write to us for particulars and recommendations.

Photograph by courtesy of Messrs. Marfleet & Weight Ltd. Melbourne, Australia.

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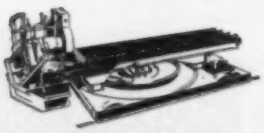
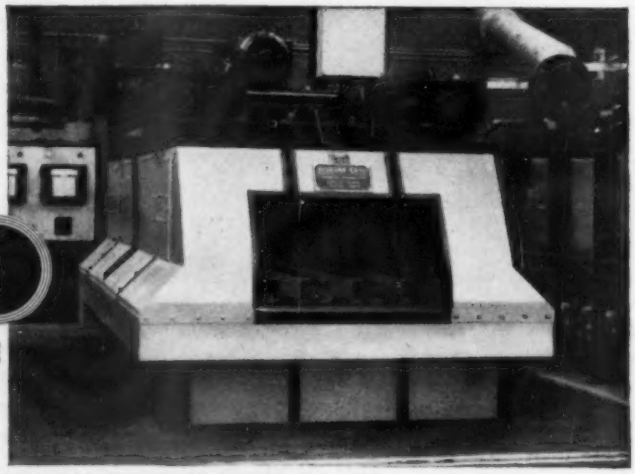


The Gibbons-van Marle Charging Machine is a natural complement to the Gibbons Quenching Machine.

All enquiries to **GIBBONS BROTHERS LTD.**, Dibdale, Dudley, Worcs. Tel: Dudley 55141 (P.B.X.)



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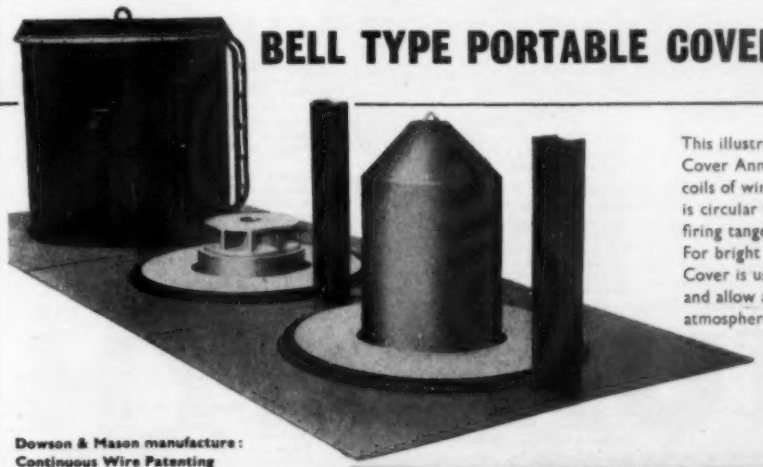
BELL TYPE PORTABLE COVER FURNACE



This illustration shows a Portable Cover Annealing Furnace for coils of wire or strip. The cover is circular with gas burners firing tangentially.
For bright annealing, an inner Cover is used to enclose the coils and allow a prepared gas atmosphere to be applied.

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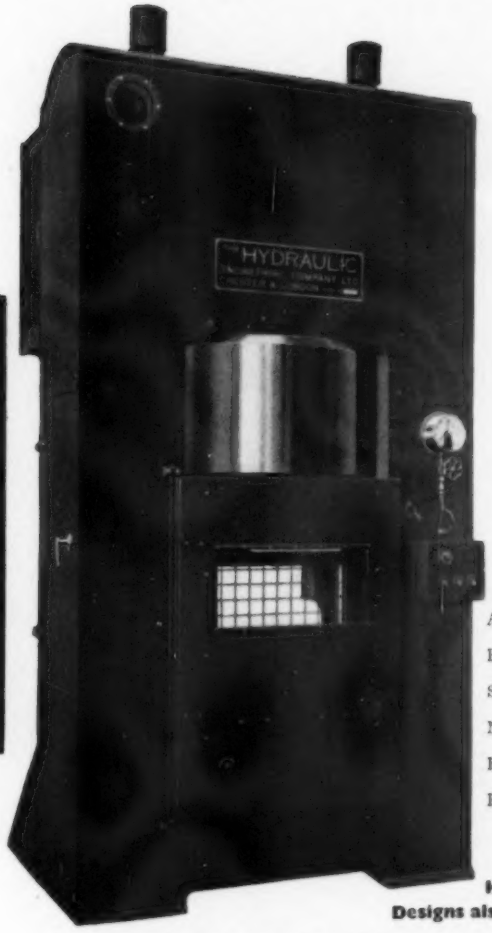

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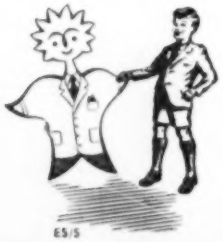

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